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ABSTRACT

Designed to help unemployed and disadvantaged workers find new career opportunities, this curriculum provides vocational students with a basic course of instruction in pulsed tungsten inert gas (TIG) welding. The first of four sections provides a general background of welding, the welding industry, and welding processes. Section 2 focuses on establishing a pulsed TIG welding program. Specific components that are discussed include the need for vocational training, student education/experience background, visual aids, equipment, supplies, and safety. The third section provides the in-depth technical detail of the pulsed TIG welding process. Topics included are (1) technical details, (2) advantages of pulsing, (3) welding machines, (4) welding torches, (5) tungsten electrodes, (6) filler rods, (7) shielding gases, (8) gas flow rate, and (9) materials to be welded. The final section contains lesson plans for ten units of instruction. Each lesson plan is further divided into the lesson objective, equipment and materials needed, lecture/discussion topics, and procedures. Appended material includes a users guide for the Miller Syncrowave 300, welding career statistics, and a discussion of women in welding. (IRA)

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FINAL REPORT

of

PROJECT CURRICULUM DEVELPOMENT

PULSED TIG WELDING

1978 - 1979

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PREFACE

This text is designed to provide vocational school students with a basic course of instruction in Pulsed Tungsten Inert Gas (TIG) welding. It was developed as part of a vocational education contract to help unemployed and disadvantaged workers find new career opportunities as welders.

The text is divided into two parts:

Section One provides a general background of welding, the welding industry, and welding processes to help familiarize students with the technical material that follows.

The remaining section provides the in-depth technical detail of the Pulsed-TIG process and the lesson plans that form the core of the curriculum. The lesson plans are designed to be self-explanatory, enabling the student to progress at his/her own pace. The successful completion of this curriculum will provide the student with the basic foundation for entry into the welding industry as a Pulsed-TIG welder.

This program alone will not make finished welders out of every student. How the student applies his/her efforts will determine how effective this course of instruction is. If the student studies hard and practices the techniques described by this program, he/she will have a strong base for the future to develop the necessary qualifications for welding certification.

ACKNOWLEDGEMENTS

This text would not have been possible without the cooperation and help of many people. I owe a debt of gratitude to all.

I would like to make special thanks to Mr. Edward Lazowski, Vice-Principal of the Atlantic County Area Vocational-Technical School, for his help in obtaining this grant and for his expert advice and guidance. Thanks also, to Bob Barnett, for his efforts to coordinate the research and instructional materials herein.

A special acknowledgement to the following for their cooperation in this endeavor: The Miller Electric Manufacturing Company, The Hobart Brothers Company, The Linde Division of Union Carbide, Welding Design and Fabrication, and The American Welding Society.

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GLOSSARY OF WELDING TERMS

AC ALTERNATING CURRENT - electricity that reverses its direction periodically. For 60-cycle current, the current goes in one direction, then in the other direction, 60 times in the same second. The current changes its direction 120 times in one second.

ALUMINUM OXIDE - a thin film that forms on the surface of aluminum due to a reaction between the metal and oxygen in the air.

ARC LENGTH - the distance from the end of the tungsten electrode to the weld puddle. The length is usually a maximum 1/16 of an inch.

ARC VOLTAGE - the voltage across the welding arc.

BASE METAL - the metal to be welded.

BUTT JOINT - a joint between two members (pieces of metal) lying approximately in the same plane.

COLLET - a chucking device used to hold the tungsten in the torch.

COLLET BODY - a holding device for the collet.

COMPLETE JOINT PENETRATION - weld penetration that extends completely through the joint.

CRATER OUT - this is performed at the end of a weld by reducing the welding current while filling the crater.

CYLINDER - a portable cylindrical container used for transportation and storage of a compressed gas.

DC OR DIRECT CURRENT - electric current that flows only in one direction.

DEPTH OF FUSION - the distance that fusion extends into the base metal or previous pass from the surface melted during welding.

DOWN SLOPE - determines the rate of change from weld current level down to the final current. Helps to "tail out" the crater which in turn makes it easier to terminate a bead nicely to avoid a "crater" finish.

FILLER METAL - the metal to be added in making a welded joint.

FLAT POSITION - the welding position used to weld the upper side of the joint. The face of the weld is approximately horizontal.

FLOW METER - a calibrated metering device used to regulate the flow of gases to the torch and measured in cubic feet per hour (FT3/h).

GAS METAL ARC WELDING - an arc-welding process wherin coalescence is produced by heating with an arc between a single tungsten (nonconsumable) electrode and the work piece. Shielding is obtained from a gas or gas mixture. Pressure may or may not be used and filler rod may or may not be used. This process is more commonly called TIG welding.

HEAT AFFECTED ZONE - that portion of the base metal which has not been melted, but whose mechanical properties or micro-structure have been altered by the heat of welding.

HIGH FREQUENCY CONTROL - a control used to increase or decrease high frequency intensity. Set the control high enough to make starting of the arc easy without touching the tungsten against the work piece. If it is too low, the arc will not start. If it is too high, the arc will start too far from the work and will cause "specking" and may cause tungsten "spitting".

HIGH PULSE CURRENT (OR PULSE CURRENT) - is the current during the high-pulse time and this produces the high heat level.

HIGH PULSE TIME - is the time duration of the high current pulse.

INERT GAS - a gas which does not normally combine chemically with the base metal or filler metal. It acts as a protective shield from atmosphere for the molten weld puddle.

JOINT PENETRATION - the minimum depth a groove or flange weld extends from its face into a joint, exclusive of reinforcement.

KEYHOLE - a technique of welding in which a concentrated heat source penetrates completely through a work piece forming a hole at the leading edge of the molten weld metal. As the heat source progresses, the molten metal fills in behind the hole to form a weld bead.

LAP JOINT - a joint between two overlapping members.

LOW PULSE CURRENT OR BACKGROUND CURRENT - is the current during the Low pulsed time that produces the low heat level.

LOW PULSE TIME - is the time duration of the Low current pulse or background current.

MOLTEN WELD POOL - the liquid state of a weld prior to solidification as weld metal.

NOZZLE - a device which directs the shielding gas through the end of the welding torch.

PASS - a single longitudinal progression of a welding operation along a joint or weld deposit. The result of a pass is a weld bead.

POROSITY - gas pockets or voids in metal.

PULSED CURRENT - two levels of welding current switched periodically between the high and low levels to produce a pulsating current or arc.

PULSED CURRENT WELDING - the pulsed current method provides a great number of advantages over conventional continuous current welding. Consistently satisfactory welds require precise control of the puddle size, the depth of penetration and the weld bead contour. By synchronizing the low pulse current and the low pulse time setting, the puddle can be allowed to cool sufficiently between the high current pulses to help control excessive penetration.

PURGIN - this is the replacement of the air environment inside a pipe or container with an inert gas (usually argon). It is used with metals that are usually sensitive to oxidization while being welded. The most common use is with stainless steels.

ROOT OF WELD - the points as shown in a cross section, at which the bottom of the weld intersects the base metal surfaces.

ROOT OPENING - the separation between members to be joints, at the root of the joint.

SCRATCH STARTING - sometimes a welding machine does not have this special high frequency innovation feature that initiates the arc without touching the tungsten electrode to the work piece.

SHIELDING GAS - a protective gas used to prevent atmospheric contamination of the weld puddle.

SPECKING - small specks of melted surface metal scattered around and just beyond the weld starting area.

SECTION 1. INTRODUCTION TO WELDING

STICKOUT - the distance from the end of the torch nozzle to the end of the tungsten electrode.

STRAIGHT POLARITY - the arrangement of the arc welding leads wherein the work piece is the positive pole and the electrode is the negative pole of the electric arc.

STRINGER BEAD - a type of weld bead made without appreciable transverse oscillation.

TACK WELD - a weld made to hold parts of a weldment in proper place for alingment until the final welds are made. Some times removed before completing welds of x-ray quality.

TEE JOINT - a joint between two members located approximately at right angles to each other in the form of a T.

THORIATED TUNGSTEN - tungsten containing a small percentage of thorium which allows the electronic emission improve the quality of the weld.

TORCH (TIG) - a handle attached to a power cable which supplies the shielding gas to the nozzle. The head attached holds the tungsten which can either be air cooled or water cooled depending on the amperage used.

TUNGSTEN ELECTRODE - a non-filler metal electrode used in gas metal arc welding, consisting of a very hard steel-gray metal which melts at a temperature of approximately 6150F.

WELD - a localized coalescence of metal where coalescence is produced either by heating to suitable temperatures, with or without the application of pressure, or by the application of pressure alone, and with or without the use of a filler metal. The filler metal either has a melting point approximately the same as the base metal or has a melting point below that of the base metals but above 800 degrees Farenheit (427 Centigrade).

WELDMENT - an assembly of component parts that are joined by welding.

WELDING CURRENT - the current in the welding circuit during the making of a weld.

WELDING PROCEDURE - the detailed methods and practices, including joint design, involved in the production of a weldment.

SECTION 1. INTRODUCTION TO WELDING

Modern welding technology is an important part of daily life. Welding products are everywhere--from the automobiles we drive to the machines that manufacture and process almost all our goods. Welding is an important profession, one that requires education, practical experience, and diligent application.

1.1. HISTORY OF WELDING

The craft of welding dates back thousands of years. Man's knowledge of welding is as old as the finely wrought artifacts found in the pyramids of ancient Egypt. In fact, archaeological research has shown that the techniques of welding were discovered independently by many primitive peoples who had no apparent means of inter-communications. Knowledge of welding has probably been lost and rediscovered repeatedly throughout history.

The earliest techniques of welding were forge type welds. This was one of the few skills of civilization not lost or forgotten during the dark ages. The light of the Renaissance found many craftsmen highly skilled in the techniques of forge welding. This process was similar to that used by the traditional American blacksmith: a white-hot iron is fused, using powdered borax to prevent atmospheric contamination (acts as a "flux"), by pounding iron together. A forged weld can be as strong as

any other, but since there are shapes not suitable for this type of heating and joining of metals, men started looking for better ways to weld.

The end of the 19th century arrived before any real improvements were developed in welding technology. Arc welding and resistence welding were the first two advances, steps forward that were prompted by the demands of emerging industries. Oxy-acetylene welding was also invented during this time, but it was a technique not used by industry until the early 1900s.

Arc welding was the first major technological advance in metal working since the development of forge welding. This electrical process is generally attributed to an Englishman, Sir Humphrey Davy, in 1810. Although metals may have been joined earlier by electric fusion, Davy's experiments with electricity are the best documented. He discovered that an arc could be created with a high-voltage-electric current by bringing two electrical terminals near each other. Twenty years passed before the term "arc" was coined to describe this phenomenon and it was not until the early 1860s that another Englishman, Wilde, successfully "melted" two pieces of iron together. Even though the first patent for the arc welding process was granted in 1865, electric arc welding remained nothing more than a scientific curiosity until 1881.

The "modern age" of welding technology actually began when Auguste de Meritens invented the carbon arc process in 1881. This technique, using a carbon electrode to weld lead battery plates, was the first time that an electric arc was put to a practical industrial use. By 1892 arc welding had advanced sufficiently for patents to be established for manipulating rods by hand. This increased technology enabled the Baldwin Locomotive Works to establish the first welding shop using carbon arc welding for locomotive maintenance.

At the same time, a new metal-arc process was being developed separately by Russian scientists and an American inventor named Charles Coffin. As a result of his effort, Coffin was granted a United States Patent in 1889 for the use of a metal electrode that not only supplied the fusion heat but also added filler metal to the joint. The research by the Russians produced remarkably similar results.

In the years since Charles Coffin's patent, the development of the arc welding process has slowed. Satisfactory metal electrodes were not readily available. Even today, the development of the electrode and coatings that ironize more easily is the key to the progress of arc welding. Nevertheless, arc welding still serves as a primary means of joining metals and considerable research effort is spent on welding processes that use electricity and inert gas.

As welding technology progressed and various metals were added to the metal-working industry, one problem continued to defy solution: That of joining regular reactive metals like aluminum and magnesium. The problem was that covered electrodes did not provide enough shielding to adequately protect these metals from atmospheric contamination. Gas tungsten arc welding was invented to answer this problem.

Gas tungsten arc (GTA) welding had its beginnings in experiments by Charles Coffin, inventor of the metal-arc process. Coffin's experiments were directed towards finding a means to weld in a non-oxidizing gas atmosphere. These experiments resulted in patents in 1890. The basics of this process were later refined by H. M. Hobart in the 1920s using helium for shielding, and later by P. K. Devers, who substituted argon. The specific needs of a young but growing aircraft industry hastened the development of new processes designed to weld magnesium - namely, the gas-shielded processes that are powered by Direct Current (DC).

The first gas-shielded process used tungsten electrodes and helium as a shielding gas. This technique, patented by Meridith in 1941, was named "Heliarc" welding. Heliarc later became known as "Tungsten-Inert Gas", or TIG welding. The gas tungsten arc process served an important role in the Second World War. TIG welding provided a practical solution to the problems encountered in welding aluminum pipe and similar fabrications needed for the war effort.

GTA welding is a gas-shielded arc welding process that uses the intense heat of an electric arc between a non-consumable, a non-melting electrode and the metal to be welded. An inert gas, or mixture of inert gases, shields the arc from the atmosphere. The tungsten electrode does not melt so a filler metal must be added separately. The use of GTA welding has grown as fast or faster than the overall welding industry because of its adaptability to automation. Automated welding processes are seeing more and more applications, especially for high-quality work such as nuclear piping and systems, and welding the newer thin speciality metals. Pulsing is the newest of the gas tungsten arc technologies.

Although the Pulsed-GTA process has been available for a decade, there has been little publicity of its uses and operation. The main application of this technology so far has been in automatic or mechanized welding applications. In the early 1970s, more emphasis was placed on the use of GTA in nuclear power plant construction, ship building, and the tubing industries, because of GTA's excellent root passes in the fixed position. The pulsed-welding current has proved to be a powerful technique for increasing the tolerance of welders to a varied fit-up, or geometrical variations in work.

Since the bulk of GTA welding is done manually, it is not unreasonable to forecast an increase in the use of the pulsing process. A reduction in operator skill level and training,

manipulation of equipment, and lowered electrode and filler metal usage offers great advantages to current and future users of GTA welding. Vocational training in this technology gives the welding industry a wider talent pool with more women and minorities; and offers the student an opportunity for a well paying, skill-oriented career.

1.2 INTRODUCTION TO WELDING TECHNOLOGY

In our technologically oriented society the applications of welding are virtually unlimited. Practically every item used in daily life is something that is created by welding or manufactured by a machine with welded parts. Such a wide-scale use of welded materials means that industry has a need for skilled welders in many different types of jobs and in many different geographical locations. In today's job market, welding can offer a lucrative and satisfying career.

1.2.1 TODAY'S JOB MARKET

The United States Department of Labor statistics listed in Table 1-1 show the amount of welding being done in various industries and the ranking of those industries in number of welders employed.

TABLE 1-1. WELDING JOBS BY INDUSTRY

Rank order	Industry Grouping and Definition	SIC No.	Welders & Flame %	Number
1	Fabricated metal products	34	16.8	90,268
2	Machinery, except electrical	35	15.7	84,266
3	Construction	15-17	10.3	55,416
4	Motor Vehicles and Equipment	371	7.7	41,383
5	Aircraft, Ships, Railroad equipment	372-4	7.6	40,405
6	Primary Metal Industries	33	7.2	38,711
7	Electrical Machinery, Equipment & Supplies	36	6.0	32,368
8	Transportation, Communications, and Utility Services	40-49	5.9	31,503
9	Repair Services, Auto and Misc.	75&76	5.1	27,500
10	Wholesale Trade	50	3.7	19,991
11	Mining	10-14	2.2	12,025

There are many welders who are not classified as working in "welding" jobs. In the building trades some welders may be classified as boilermakers, iron workers, or even plumbers. When thinking of welding as a career, it should be remembered that such jobs as these are not listed in labor statistics as welding. Since there is no single union for welders, welding jobs can be found under many different job titles and many different union banners. There are many more welding jobs available than might appear at first glance.

Welders entering the field begin their careers in many ways. Some have family background in the trade, others learn the trade from in-plant training programs. The high cost of in-house training has encouraged industry to make use of vocational trade schools by recruiting trade-school students into entry level welding positions.

The opportunities for employment as welders are always enhanced by formal training in the field. The student should first learn about the employment opportunities in his/her chosen geographic area and concentrate on learning the particular type of welding most common there. Well established vocational training can provide the broad based background necessary for successful employment in the welding industry.

1.2.2 TUNGSTEN INERT GAS (TIG) WELDING

The "Tungsten Inert-Gas-Shielded Arc Welding" process was originally called heliarc welding because the gas first used as a shielding gas was helium. This process is now called "Tungsten Inert Gas" welding, or "TIG", because other types of shielding gases (mainly argon) are used besides helium.

A basic understanding of the TIG process is necessary for the student to better understand what is being accomplished by the pulsing procedure. TIG welding is an extension of electric arc welding. The welding is done when an intense arc is drawn between a weldable metal and a tungsten electrode while an inert gas shields the weld area from atmospheric contaminants. TIG welding can produce welds that are far superior to other processes because TIG allows the operator control of metal distortion and also because of the cleaning action (of the weld area) inherent to the TIG process.

To more fully describe the Tungsten Inert-Gas-Shielded Arc welding process (the proper name for TIG welding), let's examine each word in the name as it relates to the process:

a. TUNGSTEN. This refers to the electrode that conducts the electric current to the arc.

b. INERT. This refers to the type of gas used. An inert gas will not combine chemically with other elements.

c. GAS. The inert gas is a shielding material that blankets the arc and molten puddle.

d. SHIELDED. The action of the inert gas to exclude atmospheric contamination from entering the weld area.

e. ARC. The weld is being accomplished by an electric arc rather than by combustion of gas.

The TIG welding process (the heat of an arc between a non-consumable tungsten electrode and the base metal) is shown more clearly in Figure 1-1.

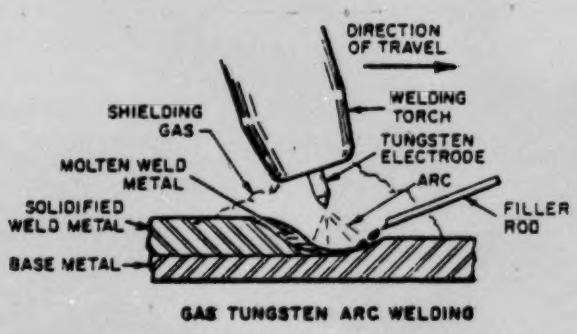


Figure 1-1. The Gas Tungsten Arc Process

The arc between the electrode and the base metal develops an intense heat which melts the surface of the base metal to form a molten pool. Filler metal (rod) is added to the weld pool by the arc of the non-consumable tungsten electrode. The arc area is protected by an inert shielding gas flowing from the nozzle of the torch. There is little or no smoke while welding and the finished weld is smooth and uniform, requiring little or no finishing.

The TIG process allows greater control for precision work because the arc and the weld pool are clearly visible to the welder. Welding can be performed in all positions, and since no filler metal is carried across the arc, there is no splatter or slag which might be trapped in the weld.

The welding circuit, as shown in Figure 1-2, is a basic setup for TIG welding. It uses filler metal (rod) and a foot control to regulate the current while welding, and water cooling when welding with high-level currents.

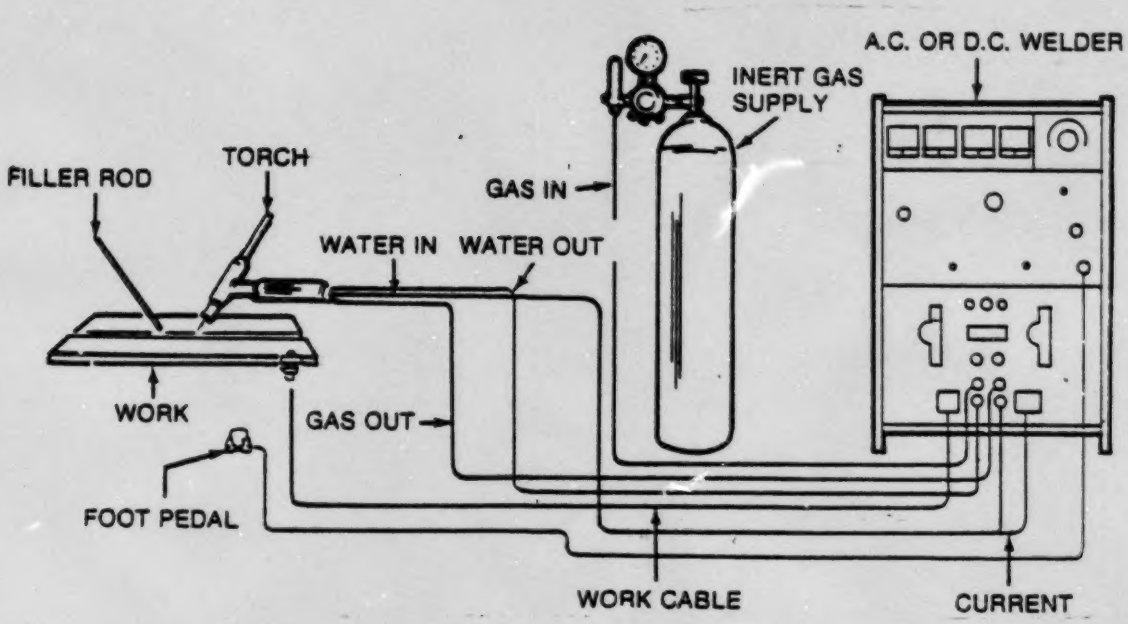


Figure 1-2. The Welding Setup

Both alternating and direct current are used for TIG welding. Direct current is used with either polarity depending on the job requirements. The polarity of the welding current has an important bearing on the completed welds. Direct current/straight polarity provides deeper penetration into the base metal. This allows a smaller electrode to maintain approximately 30 percent of the heat in the electrode while transferring 70 percent into the base metal in the narrow melted area. Direct current/reverse polarity produces the maximum heat in the electrode and the minimum heat in the base metal. The direct current penetration is shown in Figure 1-3.

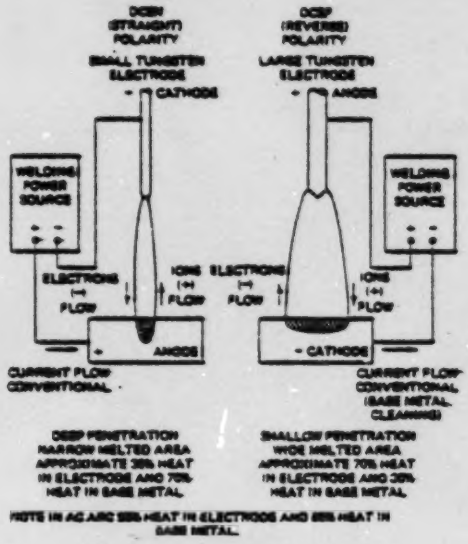

DCSP (REVERSED) POLARITY
LARGE TUNGSTEN ELECTRODE
+ ANODE
WELDING POWER SOURCE
ELECTRONS (-) FLOW
IONS (+) FLOW
- CATHODE
CURRENT FLOW CONVENTIONAL (BASE METAL CLEANING)
SHALLOW PENETRATION WIDE MELTED AREA APPROXIMATE 70% HEAT IN ELECTRODE AND 30% HEAT IN BASE METAL

Figure 1-3. Weld Current Penetration

An alternating current (ac) is best suited for welding aluminum and some alloys, but must be superimposed with a high-frequency current that is allowed to operate continuously while welding. Good penetration is obtained on the negative half of the cycle, while the desired cleaning action occurs on the positive half. A common misunderstanding is that the high frequency does the cleaning. This is not true. High frequency serves to regenerate the arc and the arc does the oxide removal.

The welding torch, electrodes, and shielding gases will be discussed in greater detail later in the text, along with the metals that are suitable for welding with the TIG process.

1.2.3 PULSED-TIG WELDING

The techniques used in TIG welding for handling torch and filler metal are similar to those used in the related process of pulsed-TIG. The differences occur in how the welding current is applied. The pulsed-current method employs two levels of welding current instead of the single current used in conventional TIG welding. The welding current is switched periodically between high level and low level to produce a pulsating current or arc. This pulsed arc produces an overlapping spot weld that can be formed into a continuous welded seam. The spot weld is produced on the high level current AFTER the current is switched to the low level. The low-level current allows the melted weld spot to partially solidify before the next spot is started but maintains the arc (between "spots") to avoid re-ignition problems. The operator then moves the torch to the next point along the seam so that the arc spots overlap to produce a continuous weld. Pulsed-current arc welding can be done manually or automatically.

Figure 1-4 diagrams the type of weld produced by the pulsed-TIG process.

Top view of spots formed by pulse

A longitudinal cross section showing penetration

Figure 1-4. Pulsed-Current Weld Beads.

Pulsed-TIG helps reduce operator skill level and operator fatigue as compared to other welding processes. Pulsing eliminates or reduces many of the usual filler metal and electrode manipulations required in conventional welding. Foot pedal control is minimized and, in some cases, eliminated. Pulsed-current control serves as an added tool available to welding operators to extend skill level and assist in producing good welds.

In summary, Pulsed-TIG welding can be considered somewhat analogous to driving a car down a steep grade; the procedure to prevent overheating of the car's brake lining is to "pump" the brakes (pulsing) rather than apply steady, continuous braking action. This "pumping" action allows maximum braking force without excessive heat buildup in the brake lining. The result is better control of the car without loss of braking action, or in a welding sense, better control of the weld current without causing excessive heat to damage or distort the metal being welded.

WELDING POWER

When TIG welding, the operator has three choices of welding current. They are: direct current straight polarity, direct current reverse polarity, and alternating current with high frequency stabilization. Each of these current types has its applications, and its advantages and disadvantages. A look at each type and its uses will help the operator select the best current type for the job. Figure 9, 10, & 11 illustrate power supply connections for each current type.

The type of current used will have a great effect on the penetration pattern as well as the bead configuration. Figure 12 shows details of the arc area with each current type.

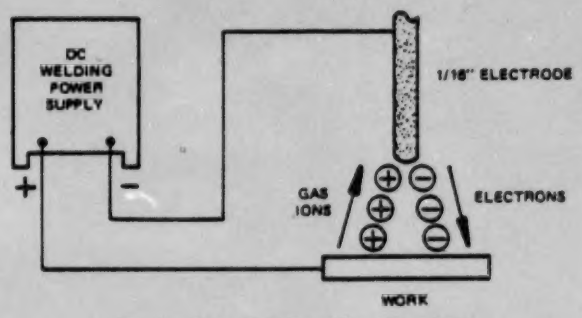


Figure 9 = DC Straight Polarity (Electrode Negative)

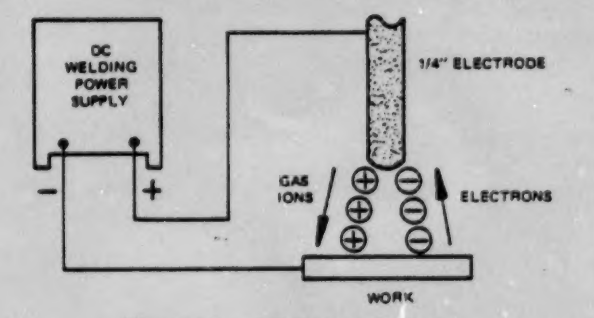


Figure 10 = DC Reverse Polarity (Electrode Positive)

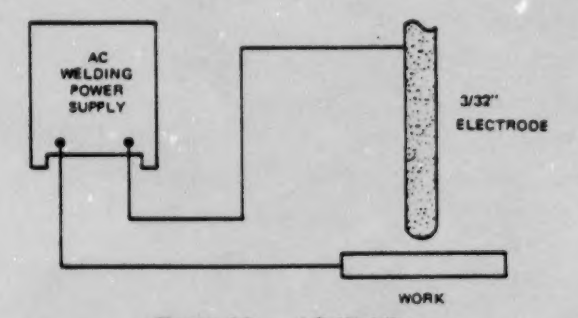
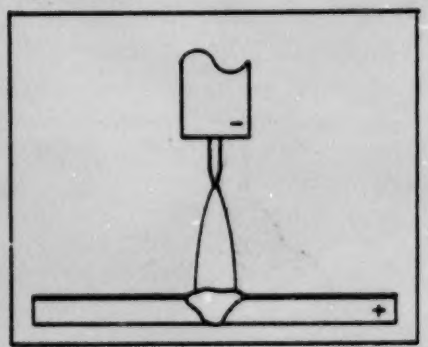


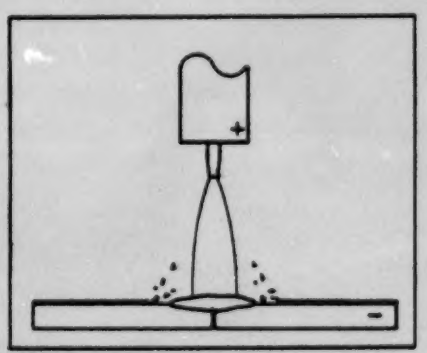
Figure 11 = AC Welding Machine Connection

Figure 1-5. Weld Current and Bead Configuration (Courtesy of The Miller Electric Company)

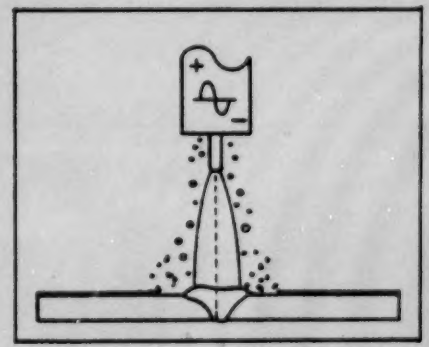
Figure 12



TIG welding with DCSP produces deep penetration because it concentrates the heat in the joint area. No cleaning action occurs with this polarity.



TIG welding with DCRP produces good cleaning action as the argon ions flowing towards the work strike with sufficient force to break up oxides on the surface. Since the electrons flowing towards the electrode cause a heating effect at the electrode, weld penetration is shallow.



TIG welding with ACHF combines the good weld penetration on the negative half cycle with the desired cleaning action of the positive half cycle. High Frequency re-establishes the arc which breaks each half cycle.

SECTION 2. ESTABLISHING A PULSED-TIG WELDING PROGRAM

SECTION 2. ESTABLISHING A PULSED-TIG WELDING PROGRAM

This section introduces a course of instruction in Pulsed-TIG welding and provides the information necessary for instructor and students to obtain maximum results in this welding technology.

2.1 THE NEED FOR VOCATIONAL TRAINING

The purpose of vocational education is to help students who are not interested in pursuing a liberal arts education to acquire the job skills and training necessary to develop satisfying and well-paying careers in a blue collar trade. The aim of vocational education is to properly motivate these students towards learning the essential skills that will be important to their future.

Welding is a skill-oriented craft that ordinarily requires many years of experience for the student to perform a satisfactory job function. Pulsed-TIG welding is an important new technique that reduces the amount of training required to learn how to weld. Proper vocational training in Pulsed-TIG welding will help the welding student obtain the necessary job skills for a welding career in less time than it would ordinarily take. Naturally, this training is not as detailed as those programs designed to produce accomplished welders.

This text explains the basic Pulsed-TIG-welding process and welding skills. The lesson plans are designed so that once the student is given the basic essentials of the course, the rest of the lessons can be accomplished unsupervised.

2.2 STUDENT EDUCATIONAL/EXPERIENCE BACKGROUND

The student entering the program should be pre-tested for general health and vision. A coordination and manipulation study should be conducted along with a test to observe the prospective student's ability to read and understand simple instructions and sketches. Although a background in welding is not necessary, experience in gas welding is helpful for hand coordination between the torch and filler metal.

2.3 VISUAL AIDS

Visual aids are helpful in classroom lecture/discussion sessions to point out the theory of the pulsing process. Graphs to illustrate the high and low pulsing actions and drawings or photographs showing the overlapping spot welds produced by the pulse cycle are useful tools to explain the new concepts these students will be learning.

Overheads or similar viewing methods can be used by producing your own drawings or by obtaining the professional aids that are available.

Two useful sources to consider are the Hobart "Pat" Programmed Audio Visual Training Program of film loops (one loop presents a motion study of pulse action) and the Miller Electric Company film entitled "The Gas Tungsten-Arc Welding Process" (a film showing arc welding through high-speed photography).

2.4 EQUIPMENT

The welding machine used to explore the various techniques set forth in this text is the Miller Synchrowave 300 shown in Figure 2-1. (The Pulsed-TIG process is NOT limited to just this machine. Other welding equipment manufacturers have similar equipment with the pulsing feature either factory installed or as an accessory unit. Note: Pulse settings and equipment specifications will vary from manufacturer to manufacturer.) Figure 2-2 shows the Synchrowave 300 controls.

miller
SYNCROWAVE 300

Figure 2-1. The Miller Synchrowave 300
(Courtesy of the Miller Electric Company)

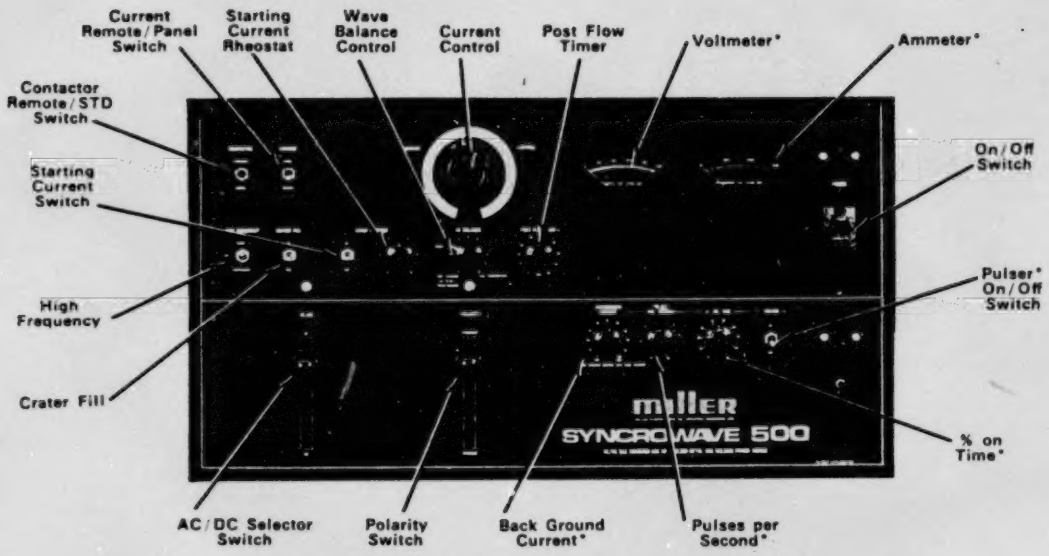


Figure 2-2. Miller Synchrowave 300 Standard Controls

(Courtesy of the Miller Electric Company)

miller

2.5 SUPPLIES

The materials needed for practice exercises may be either light gage strips, thin wall tubing, or schedule 40 piping. Heavy wall pipe of larger diameters may be used to weld the root pass in beveled joints. You may choose to use aluminum, steel, or stainless steel but you must use the proper filler material for the welding rod. The shielding gas generally used is argon, although a mixture of argon and helium can be used for deeper penetration.

In general, a well planned welding training area within a school, with proper facilities and equipment, makes it much easier to provide a successful training program. Classroom lectures may be of a short duration since live demonstrations by instructors are necessary to explore manulative skills. Proper welding fixtures are necessary in order that training exercises can be accomplished in all welding positions.

2.6 SAFETY IN WELDING

The welding industry has always maintained a keen interest in the health and safety of its welders. The American Welding Society, the United States Government, and other groups have established many safety standards for the industry.

While the safety and health of all workers is receiving national attention, health officials have found that welding is generally more hazardous than any other metal working occupation. With this in mind, it becomes essential that the proper precautionary measures must be taken to make welding a safe occupation.

Safety is an important part of any training program. In welding curriculums it is more than just a lesson in the course outline: It is an essential foundation for good, safe work habits. The application of safe welding practice must be ever-present while the student progresses in the program. It should be remembered that, while personal safety is important, the safety of others working around the welding area is also the welder's responsibility.

2.6.1 HAZARDS COMMON TO WELDING

There are certain hazardous conditions common to any welding shop. The following list contains examples of the kinds of hazards that must be guarded against.

a. Electrical shock
b. Arc radiation
c. Air contamination
d. Fire and explosion
e. Compressed gasses
f. Hot metal, cleaning welds, mechanical equipment

Common sense and the use of proper safety protection is the most effective way to reduce accidents in a welding shop.

2.6.2 WELDING DRESS AND OUTER PROTECTION

Accidents and injuries can be avoided by using proper welding dress and outer protection. The following guidelines should be observed for proper wearing apparrell in a welding shop:

a. A long sleeve shirt, buttoned at the neck.
b. Pants without cuffs.*
c. A head cap should be used in all cases.
d. High top shoes, boots preferred.
e. Safety glasses, clear or tinted.
f. Leather gloves.
g. Leather sleeves or coat.
h. A suitable helmet with clear cover glass and a proper filter glass. Shade #12 is recommended. See Figure 2-4 for an example of a suitable welding helmet.

*NOTE: Clothing with folds, cuffs, etc., provides an excellent place for sparks to lodge. Woolen clothing is also preferred to cotton since it does not disintegrate from arc radiation or catch fire as quickly.

2.6.3 SAFETY PRECAUTIONS FOR PULSED-TIG WELDING

The following precautions are suggested for Pulsed-TIG welders. (These precautions may be modified according to the individual welding area.)

a. Make sure that the welding equipment is installed properly, is grounded, and is in good working condition.

b. Always wear suitable clothing.

c. Always wear proper eye protection.

d. Keep the work area clean and free from hazards. Make sure that no flammable, volatile, or explosive materials are in or near the work area.

e. Handle all compressed gas cylinders with extreme care.

f. When the welding torch is not in use, hang it on brackets--never let it touch the compressed gas cylinders.

g. Make sure that the arc radiation produced from welding does not interfere with others.

h. When using water-cooled equipment, check for water leaks.

i. Use proper exhaust ventilation to get rid of fumes. Mechanical ventilation should be at the rate of 200 cubic feet per minute for each welder.

j. Do not weld in confined spaces without special precautions.

Safety is the watch word in the welding industry. Horse-play can never be tolerated. The welder who says "watch your eyes" BEFORE he lowers his helmet to weld is like the golfer who shouts "fore" before teeing off - always being alert to those around him.

SECTION 3. PULSED-TIG (GTA) WELDING

SECTION 3. PULSED TIG (GTA) WELDING

Pulsed Gas Tungsten Arc (GTA) welding, better known as "Pulsed-TIG", has been used mostly as an automatic or mechanized process. Since the early 1970s the rearch being done with Pulsed-TIG has shown the effectiveness of using pulsing for manual welding applications.

The use of manual Pulsed-GTA welding is increasing in the building of nuclear power plants, shipbuilding, and the tubing industries. Pulsed-GTA welding technology offers the user excellent root passes in the fixed position. (A root pass is a series of overlapping spot welds that form a continuous weld.) Pulsed-GTA is also a powerful technique for increasing the tolerance of welding to varied fit-up or geometrical variations in the work piece. It is also now finding wider use in thin gage metal fabrication because excess heat input is easily controlled and reduces the chances of heat damage to thin metals.

3.1 TECHNICAL DETAILS

Pulsed-TIG welding is a GTA welding process characterized by a repetitive variation of arc current that causes periods of high and low heat input to the weld joint. The ratio of welding heat input between the high and low levels can range from 2:1 to 10:1. Control of this heat input is obtained by choosing the repetition

rate (pulse frequency, pulses/second) and the time duration of high heat level and low heat level periods. The total time duration of high to low current level represents a pulse "cycle".

When Pulsed-TIG welding is done manually the operator must maintain a constant travel speed (the speed of the torch along the weld) in order to synchronize the movement of the torch with the current pulses to ensure proper overlapping of the spot welds. Each impulse performs melting and penetration during the pulse, followed by controlled cooling and solidification during the interpulse. The pulse process includes pulse wave shape, pulse current, background current, pulse time, and interpulse time. These important variables control penetration, bead width, puddle, agitation, and heat input. Figure 3-1 provides a graphic explanation of pulsed-current terminology.

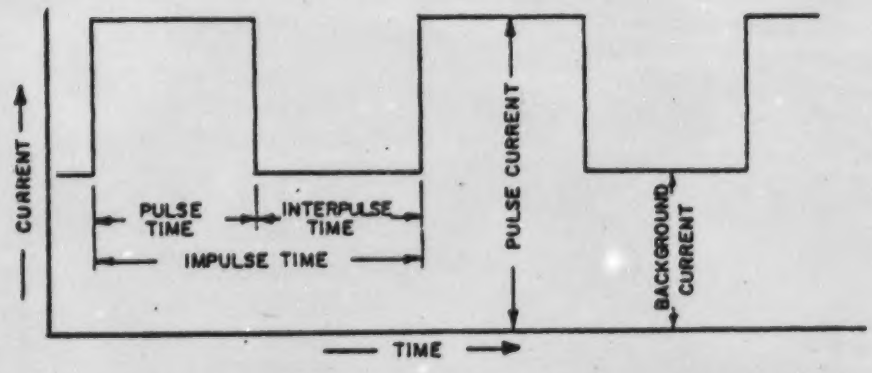


Figure 3-1. Pulsed Current Terminology

The pulsed welding technique is more tolerant of different welding positions because it can produce a continuous weld bead without the need for varying the travel speed, voltage, or current. This tolerance exists because the volume of the molten puddle is smaller when using pulsed current. The molten puddle is controlled by the proper machine settings. The welding machine must have a fairly wide range of settings to accomodate all of the various metallurgical controls necessary to produce a satisfactory weld.

3.2 THE ADVANTAGES OF PULSING

Why use Pulsed-TIG? The answer is the continuous manipulations that a welder must perform with conventional processes. Welding operators are faced with continuous juggling of such factors as:

a. Heat input (through arc length manipulation and/or foot pedal current control).
b. Puddle size.
c. Puddle fluidity.
d. Weld speed.
e. Gravity effects.
f. Penetration.

In addition, each factor has complications of its own, such as:

a. The type of material being used.
b. The welding position.
c. Joint design, or
d. Joint fit-up.

Once the technical factors of TIG welding are mastered, the actual physical limitations of the operator must be considered.

Welding operations are often performed under difficult physical circumstances. Long hours and tight, difficult working conditions affect a welder's ability to perform in exactly the same way on each weld. The uniformity of the weld is critical to making an acceptable product. The welder's problem is this: He must perform repeated welds while in awkward positions; while performing these welds he must maintain the foot control in the correct position and maintain the uniformity of the weld speed; and he must meet the production deadlines that his company has set. In addition to all this, each weld must meet welding industry standards for the work to be acceptable.

The Pulsed-TIG process makes manual welding simpler by reducing the manipulations required to make a weld. Pulsing applies heat to the base metal in periodic, controlled bursts. This is done by causing the weld current to automatically increase and decrease at regular repetition rates, much like the way an

operator pumps the foot pedal control to control current in the conventional TIG process. This power variation to the base metal provides both a "fusion" and a "freeze" period during the weld. This allows the operator to match the heat input to the thermal·characteristics of the work and obtaining better weld puddle control. Thus, by having the machine perform some of the manipulations formerly done by the operator (such as the foot pedal current control), the operator can devote more attention to producing quality welds - even under adverse physical conditions.

To summarize, Pulsed TIG:

a. Causes less distortion in the metal.
b. Requires less foot control manipulation.
c. Is easier to control weld speed with.
d. Filler metal addition is more easily controlled, and
e. Requires less overall operator skill.

These factors all add up to a reduction in the fatigue that can be caused when operating with the critical arc length and current control normally required in conventional TIG welding.

There are other advantages to Pulsed-TIG, especially in the areas of pipe welding and the welding of special alloys. Pulsed-TIG has proven to be an affective way of making operators more productive, and this means reduced finishing costs for the manufacturer.

3.3 THE WELDING MACHINE

The welding equipment used for this text is the Miller Synchro-wave 300. (Appendix A provides more detail on this machine.) The general operation of other manufacturers Pulsed-TIG welders is similar and the instructions provided in this section can serve as a guideline for learning the operation of other similar equipment. Figure 3-2 shows the control functions of a typical Pulsed-TIG welder and explains their use.

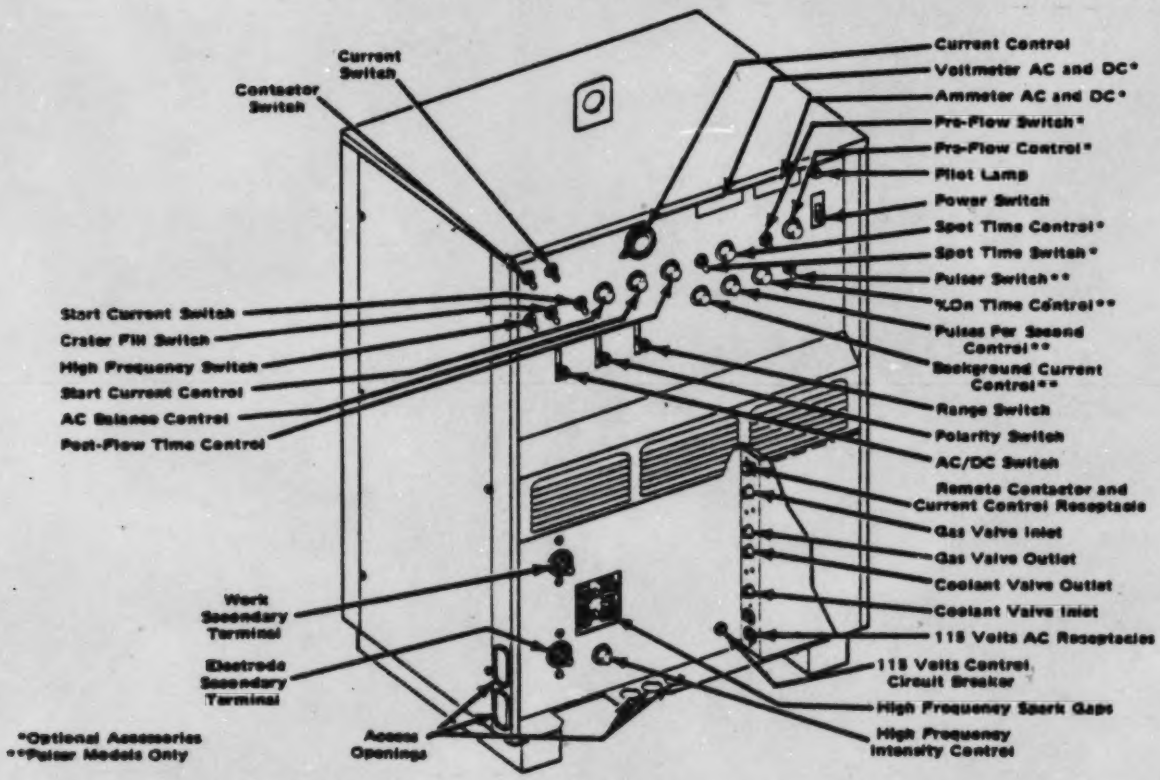


Figure 3-2. Function of Controls

(Courtesy of the Miller Electric Company)

3.3.1 THE FOOT CONTROL

The foot control of a Pulsed-TIG welding machine is similiar to the gas pedal of an automobile - it controls the "speed" of the welding current; the more the current, the hotter the weld. In Pulsed-TIG welding, the foot control is not essential when working with steel. It is, however, useful when welding aluminum because of the way aluminum conducts heat. Using the foot control enables the pulse-TIG welder to apply a lot of heat to the initial weld and then lessen the current as the aluminum heats. Figure 3-3 shows an example of a typical foot control assembly.

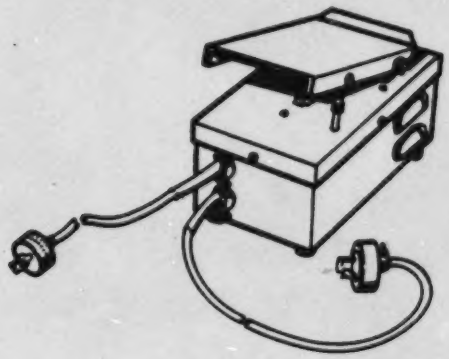


Figure 3-3. The Foot Control Unit

3.4 THE WELDING TORCH

The torch used in manual Pulsed-TIG welding can be either an air-cooled torch or a water-cooled torch.

The water-cooled torch is recommended when high production is necessary or when high amperage is needed (such as in welding heavy metals or in pipe welding). The air-cooled torch is used on light gage material when amperage requirements are low.

A water-cooled torch is designed so that water is circulated through the torch, cooling the head and the power cable. The power cable is contained inside a hose and water returning from the head flows around the power cable helping to keep it cool.

Figure 3-4 shows a typical water-cooled torch. Notice the collet body. Caution must be taken when changing this body (to accomodate the various sizes of electrodes) in order not to strip the fine copper threads by cross-threading into the steel head.

The air-cooled torches are popular since a majority of gas tungsten arc welding is done on light metals. The single cable to the torch head makes it lighter and easily manipulated for handling delicate work. The air cooled torches come in a variety of designs to suit different welding operations. Figure 3-5 shows an air-cooled torch.

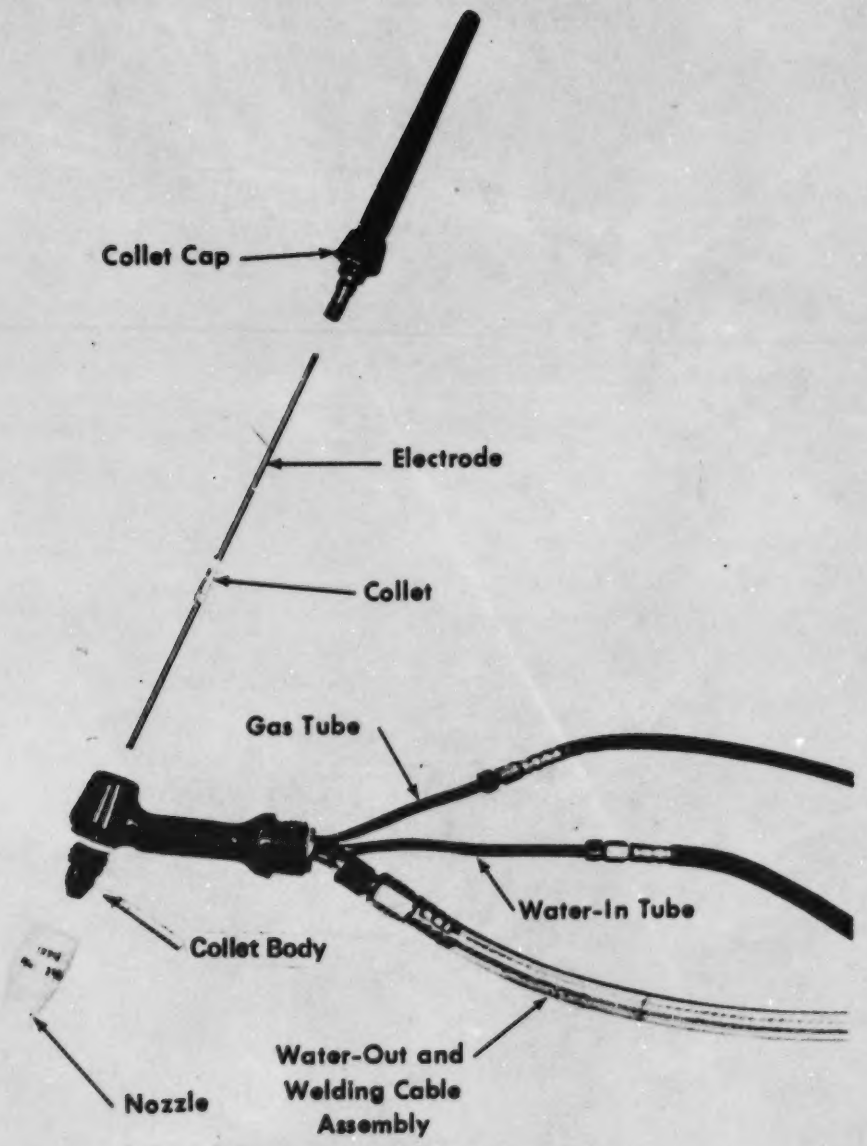


Figure 3-4. Water-Cooled Torch Assembly

Care must be taken by the operator to see that the torch is properly stored when not in use; it is a fragile assembly and will not take abuse.

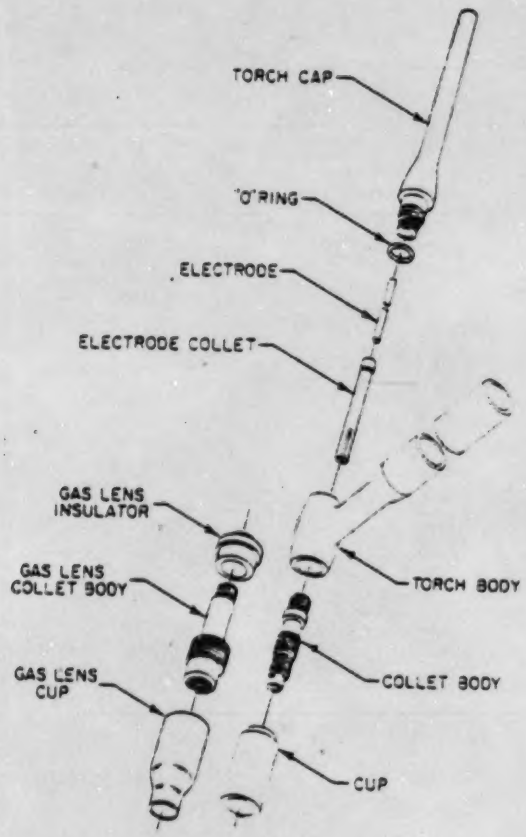


Figure 3-5. The Air-Cooled Torch

3.4.1 CERAMIC NOZZLES

The ceramic nozzle (or cup) as shown in figures 3-6 and 3-7 is used to direct the shielding gas flow to the weld puddle. Manufacturers of ceramic nozzles number these cups numerically (4, 5, 6, 7, etc.) to indicate the inside diameter of the orifice and give the nozzle size in sixteenths of an inch. A #6 nozzle, for example, has a "6/16" or 3/8 inch inside diameter. The general rule is that the inside diameter of the nozzle should be four to six times the diameter of the tungsten being used. A nozzle might overheat, break, or disintegrate if the inside diameter is too small. Ceramic nozzles are usually used in air-cooled torches for currents up to 275 amps. Special torches with water-cooled nozzles are used for higher amperages.

3.4.2 ELECTRODE STICK-OUT

The length that the tungsten electrode extends beyond the nozzle opening is an important factor. Figure 3-8 shows the general rule for electrode "stick-out". Exceptions are made for applications where specially designed nozzles are used.

3.5 THE TUNGSTEN ELECTRODE

Electrodes are supplied in diameters from .010 to .25 of an inch, and from 3 to 24 inches in length. Electrodes are made

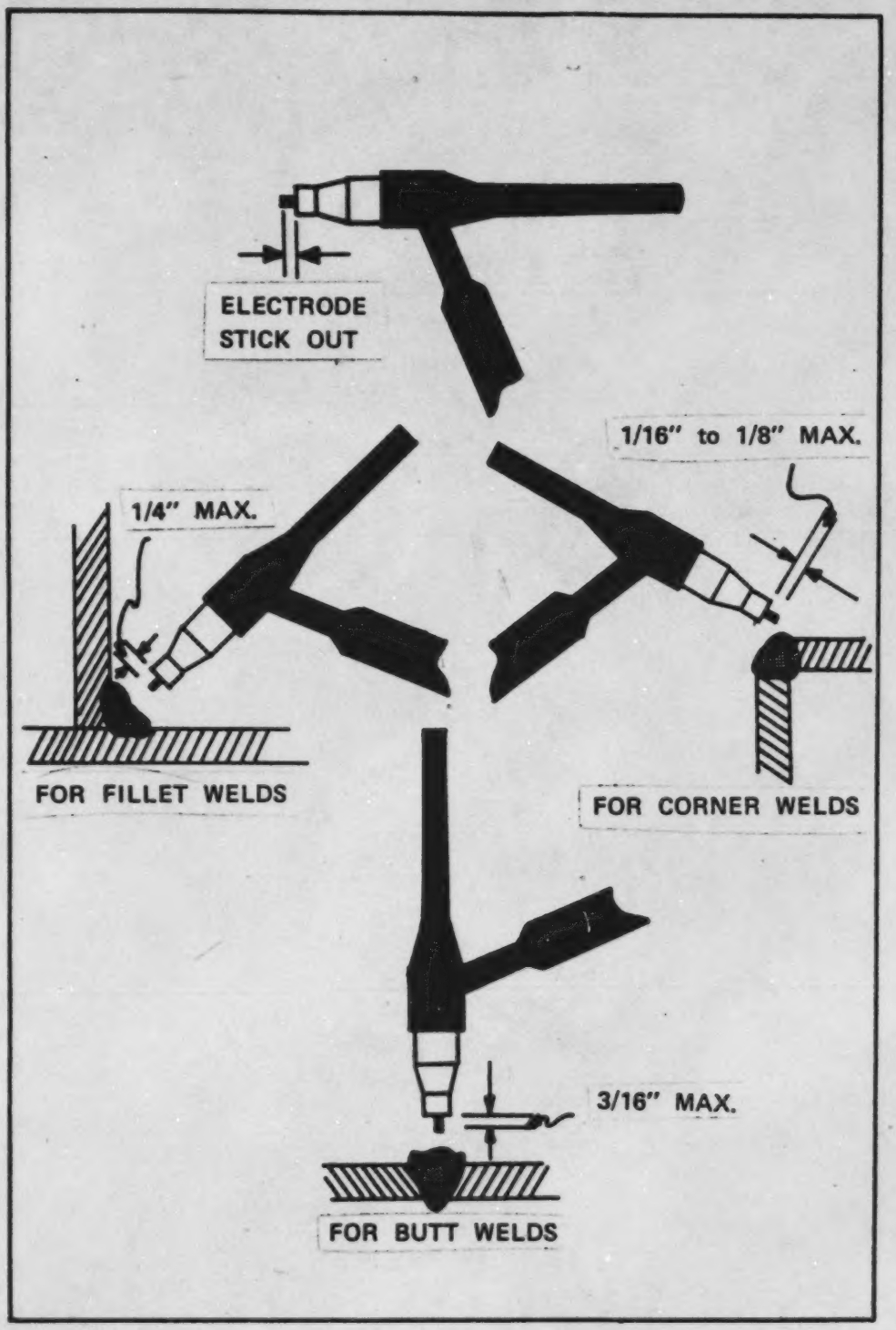


Figure 3-8. Electrode Stickout

from tungsten, a very hard steel-grey metal with a melting point of almost 6200 degrees Farenheit. They are provided to the user with a surface that is either chemically cleaned or etched, or with a ground finish that holds the diameter to a closer tolerance. Electrodes are supplied in pure tungsten, and in three alloys: one percent thorium, two percent thorium, and zirconium alloy. All three types of alloys are used in Pulsed-TIG welding. It is important for the electrode diameter to match the proper current value to give the electrode longer life.

It is necessary for the welding operator to know the classification of the electrode to be used for a given job. Misuse can cause a serious reduction in the quality of the weld. Electrodes are classified by type as shown in Table 3-1.

TABLE 3-1. ELECTRODE CLASSIFICATIONS

AWS Classification	Color Code	Chemical Requirements	Recommended Uses
EWP	Green	Tungsten 99.50 Other 0.50	Non-Ferrous metals
WTh-1	Yellow	Tungsten 98.50 Other 1.50	Ferrous metals Copper alloys
EWTh-2	Red	Tungsten 98.00 Other 2.00	Ferrous metals Copper alloys
EWZr	Brown	Tungsten 98.60 Zircoma 1.40	Non-Ferrous metals

There are many factors to be considered when selecting an electrode. One of the main considerations is the welding current. Welding current is determined by several factors, such as base metal and thickness, joint design, fit-up, the welding position, shielding gas, type of torch, and other specifications related to the type of job being done. Table 3-2 has been prepared from a composite of recommendations from the American Welding Society and electrode manufacturers to help guide the welder in the proper selection of the electrode.

TABLE 3-2. ELECTRODE RECOMMENDATIONS

PURE TUNGSTEN	CURRENT RANGE—AMPERES			
DIAMETER	DCSP-Argon	DCRP-Argon	ACHF-Argon	AC Balanced Wave-Argon
.010"	Up to 15	*	Up to 15	Up to 10
.020"	5-20	*	5-20	10-20
.040"	15-80	*	10-60	20-30
1/16"	70-150	10-20	50-100	30-80
3/32"	125-225	15-30	100-160	60-130
1/8"	225-360	25-40	150-210	100-180
5/32"	360-450	40-55	200-275	160-240
3/16"	450-720	55-80	250-350	190-300
1/4"	720-950	80-125	325-450	250-400
2% THORIUM ALLOYED TUNGSTEN DIAMETER				
.010"	Up to 25	*	Up to 20	Up to 15
.020"	15-40	*	15-35	5-20
.040"	25-85	*	20-80	20-60
1/16"	50-160	10-20	50-150	60-120
3/32"	135-235	15-30	130-250	100-180
1/8"	250-400	25-40	225-360	160-250
5/32"	400-500	40-55	300-450	200-320
3/16"	500-750	55-80	400-550	290-390
1/4"	750-1000	80-125	600-800	340-525
ZIRCONIUM ALLOYED TUNGSTEN DIAMETER				
.010"	*	*	Up to 20	Up to 15
.020"	*	*	15-35	5-20
.040"	*	*	20-80	20-60
1/16"	*	*	50-150	60-120
3/32"	*	*	130-250	100-180
1/8"	*	*	225-360	160-250
5/32"	*	*	300-450	200-320
3/16"	*	*	400-550	290-390
1/4"	*	*	600-800	340-525

* NOT RECOMMENDED
The figures listed are intended as a guide, and are a composite of recommendations from American Welding Society and electrode manufacturers.

After the proper size and type of electrode has been decided, how the electrode is to be used will determine its performance and life span. Contamination of an electrode can occur in several ways. The most common form of contamination is contact between the electrode and weld puddle or the electrode and the filler rod. Loss of shielding gas or contamination of the shielding gas due to leaking connections or damaged gas hoses also can contaminate the electrode. Excessive gas flow rates and/or nozzles that are dirty, chipped, or broken cause turbulence in the shielding gas, bringing atmospheric air into the welding area, thus causing contamination.

An electrode contaminated by contact with the puddle or filler rod has a deposit of metal on the electrode. If this is not too serious, maintaining an arc on a scrap piece of metal may vaporize the deposit from the electrode. If the contaminated portion cannot be removed in this manner, it must be broken off and the electrode re-shaped as necessary.

Figure 3-9 shows a number of 1/8-inch tungsten electrodes that demonstrate different tip configurations and some common tip appearances.

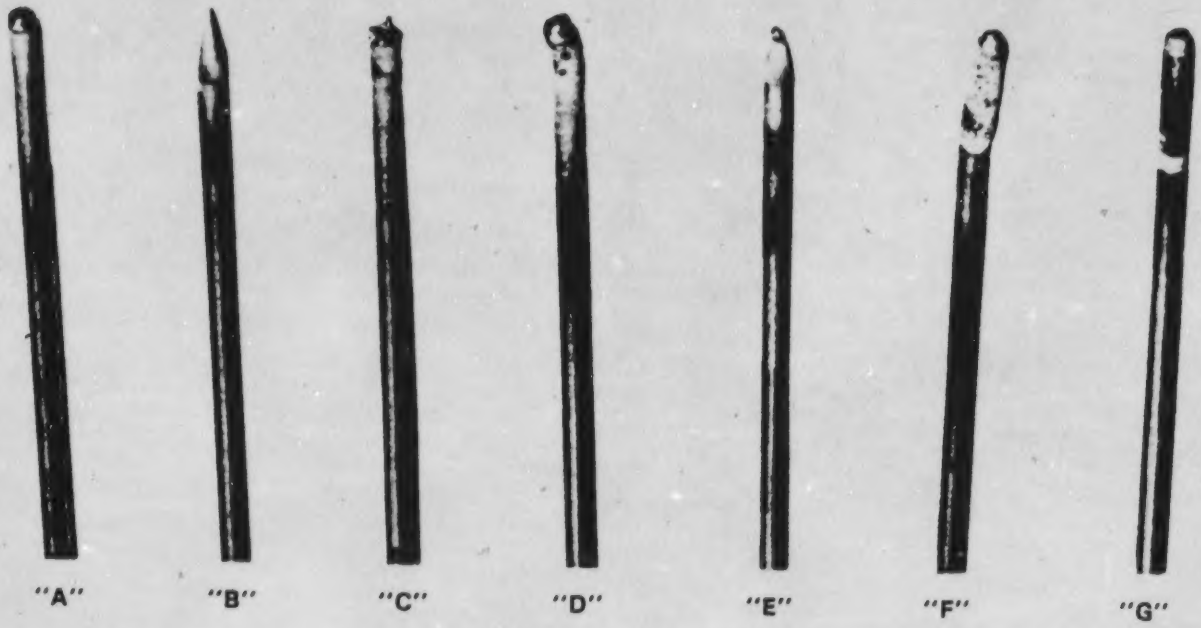


Figure 3-9. Common Welding Tip Problems

The following references correspond with those electrodes illustrated in Figure 3-9:

a. Electrode "A" has a ball end. This pure tungsten was used with alternating current on aluminum. Note that the end is uniform in shape and possesses a "shiny, bright" appearance.

b. Electrode "B" is a two percent thoriated tungsten sharpened to a taper. This electrode was used with direct current, straight polarity.

c. Electrode "C" is a two percent thoriated tungsten that was used with alternating current on aluminum. Note that this electrode has several small ball-shaped projections rather than a round, complete "ball end" like pure tungsten.

d. Electrode "D" is a pure tungsten used with alternating current on aluminum. This electrode was subject to a current above the rated capacity. Notice that the ball started to droop to one side. It had become very molten during operation. Continuing to operate would have caused the molten to drop into the weld puddle.

e. Electrode "E" is a pure tungsten that was tapered to a point and used on direct current, straight polarity. Notice the ball tip characteristic of pure tungsten. Pointing of the pure tungsten is not recommended since the extreme point will always melt once the arc is established.

f. Electrode "F" was severely contaminated by touching the filler rod to the tungsten. In this case, the contaminated area must be broken off and the electrode re-shaped.

g. Electrode "G" did not have sufficient gas "postflow". Notice the black surface oxidation caused when the atmosphere contacted the electrode before the electrode had cooled sufficiently. If this electrode were used as is, the oxidized surface would flake off and drop into the weld puddle, contaminating the weld. Postflow time should be increased here so that the tip appears like electrode "A" after welding.

3.6 THE FILLER ROD

When using the GTA process to weld heavy metals it is frequently necessary to add filler metal in order to reinforce the joint that is being welded. Filler metal is not normally required on light gage materials (depending on the type of joint to be welded) since the lighter metals can be made to readily flow together.

Filler rod material must be the same composition as that of the base metal to be welded. Mild steel rod, for example, can be used for welding low carbon steels, aluminum rods for welding aluminum, and stainless steel rod for stainless steel. Sometimes strips of the parent metal can be used as a satisfactory filler metal. Generally, the filler rod should be about the same thickness as the metal to be welded.

Special filler rods are available for TIG welding. These special rods contain a greater amount of deoxidizers that help reduce the spattering in the weld and produce a sounder weld joint.

Selecting the right filler rod is a matter of analyzing the conditions of a particular job and determining the type and size of the rod best suited for these conditions. The decision is easier if the welder always keeps the following factors in mind:

a. What is the base metal to be welded?
b. What are the dimensions of the section to be welded?
c. What type of current is available?

d. What welding position(s) will be used?

e. What sort of fit up does the work permit?

f. Must weld deposit possess any specific properties, such as corrosion resistance, high tensile strength, ductility, etc.?

g. Must weld meet requirements of any code, standard, or specifications such as ASME Boiler Code, or government specifications?

By carefully checking the above factors the welder should have no difficulty in selecting the proper filler rod. Filler rods are available as described in Table 3-3.

TABLE 3-3. FILLER ROD CLASSIFICATION

MILD STEEL WIRES	
E-60S-1	Silicon deoxidized wire for low and medium-carbon steels. Performs best on killed steels.
E-60S-2	Premium quality wire containing Al, Zr, and Ti in addition to silicone and manganese deoxidizers. Recommended for pipe welding.
E-60S-3	Used for higher quality welding. Produces medium quality welds in rimmed steels and high quality welds in semi-killed steels.
E-70S-1B	Low-alloy wire for carbon steels, low-alloy steels, and high strength low-alloy steels.
E-70S-3	General purpose welding of low to medium-carbon steels. Has a silicon content.

3.7 SHIELDING GASES

A shielding gas is used to produce an atmosphere free from contamination and provide a path for arc transfer. This path creates an environment that helps stabilize the arc. The gas and arc activity also perform a cleansing action on the base metal. Both argon and helium are commonly used as shielding gases, but argon is cheaper and provides a smoother arc. (Helium produces deeper penetration.)

There are various types and combinations of shielding gases used in the welding industry. These gases are usually stored in portable containers as a convenient way for transporting to the job site. Where a high volume of gas is required, the bulk storage or manufacturing systems are used. In Pulsed-TIG, argon and helium are the most frequently used gases. Table 3-4 describes the selection of proper shielding gases in more detail.

ARGON is a non-flammable compressed gas generally supplied in 244 or 330 cubic-foot cylinders with full pressures of 2,200 to 2,640 pounds per square inch (PSI) at 70 degrees Farenheit.

HELIUM is a non-flammable compressed gas that is supplied in a cylinder of 213 cubic feet with a full pressure of 2,200 PSI.

When welding with a gas tungsten arc process only inert gases are used. There are a few exceptions. One is a mixture of

TABLE 3-4. SELECTION OF GASES

METAL	TYPE	GAS	RESULT
Al	Manual welding	Argon	Better arc starting, cleaning action and weld quality; lower gas consumption
		Helium	High welding speeds possible
	Machine welding	Argon-Helium	Better weld quality, lower gas flow than required with straight helium
Mg	0–1/16"	Helium	Controlled penetration
	0–1/16" +	Argon	Excellent cleaning, ease of puddle manipulation, low gas flows
Mild Steel	0–1/8"	Argon	Ease of manipulation, freedom from overheating
	0–1/8" +		(Mig process preferred)
	Spot welding	Argon	Generally preferred for longer electrode life
			Better weld nugget contour
			Ease of starting, lower gas flow
		Argon-Helium	Helium addition improves penetration on heavy gage metal
	Manual welding	Argon	Better puddle control, especially for position welding
SS	Machine welding	Argon	Permits controlled penetration on thin gage material (up to 14 gage)
		Argon-Helium	Higher heat input, higher welding speeds possible on heavier gages
		Argon-Hydrogen (65%–35%)	Prevents undercutting, produces desirable weld contour at low current levels, requires lower gas flows
		Helium	Provides highest heat input and deepest penetration
Cu & Ni Cu–Ni Alloys (Monel & Inconel)		Argon	Ease of obtaining puddle control, penetration, and bead contour on thin gage metal
		Argon-Helium	Higher heat input to offset high heat conductivity of heavier gages
		Helium	Highest heat input for high welding speed on heavy metal sections
Ti		Argon	Low gas flow rate minimize turbulence and air contamination of weld; improved metal transfer; improved heat affected zone
		Helium	Better penetration for manual welding of thick sections (inert gas backing required to shield back of weld against contamination)
Si Bronze		Argon	Reduces cracking of this 'hot short' metal
Al Bronze		Argon	Less penetration of base metal

inert gas with a reducing active gas such as hydrogen, or mixing a small amount of oxygen. Oxygen is limited to 5 percent and is used to improve the weld penetration and also improves the weld contour. A gas mixture of argon and helium is used when welding heavier weldments of nonferrous materials, and is helpful when welding in the overhead position.

In the lesson plans of this text, argon is used as the shielding gas. Therefore, we should understand its function and shielding properties. Argon gas is colorless, odorless, tasteless and non-toxic. Being inert, it forms no known chemical compound. The purity of argon gas for welding is approximately 99.995 percent and it is a relatively heavy gas, approximately 23 percent heavier than air. Argon has a low ironization potential and the voltage of the tungsten arc in argon is considerably lower than in helium. The welding arc tends to be stable and for this reason argon is used in many shielding gas mixtures. The main purpose of a shielding gas is to eliminate the porosity in the weld and also to prevent corrosion and weld cracking. In order to control these problems, it is important to check the gas supply lines for leaks to prevent impure shielding gases from reaching the weld area. Dirty welds, particularly on aluminum, is a frequent problem of improper shielding action.

The shielding gas coverage is a critical factor in the weld area since it depends on the purity of the gas and the gas

flow rate. Caution must also be taken to eliminate any wind or breezes that might blow the shielding gas away while welding. Table 3-4 describes available shielding gases and their use.

3.8 GAS FLOW RATE

While the shielding gas is important in making an acceptable weld, the rate of flow is also important. The gas is regulated from the storage tank by the means of a flow-meter regulator. The flow meter is attached to the tank or supply line, in a vertical position. This allows the steel ball in the glass tube to move freely and give an accurate reading. The shielding gas flow is rated by cubic foot per hour (ft^3/h) and can be regulated by the adjusting valve. (See Figure 3-10.) The gas flow is measured at the top of the ball. The amount of shielding gas necessary varies with the welding requirements. When the welding operation is completed, the regulator should be shut off and the line drained. Figure 3-11 shows a floating ball type flowmeter.

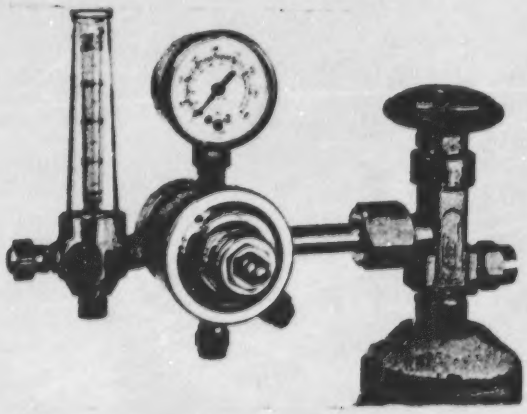
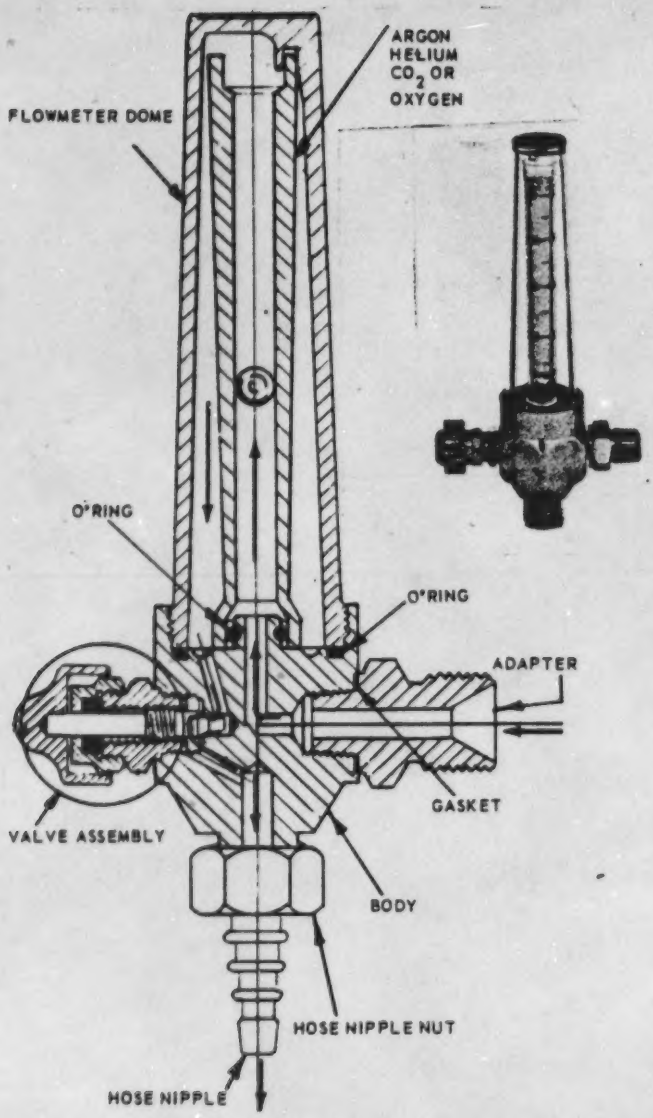


Figure 3-10. Argon Gas Cylinder with Regulator and Flowmeter



Cross section of a floating ball type flowmeter.

Figure 3-11. Floating Ball Type Flowmeter

3.9 MATERIALS TO BE WELDED

There are many metals that can be welded with the gas tungsten arc processes. Each metal presents its own special problems and level of difficulty to the welding operator. Table 3-5 presents a summary of weldable metals. In most cases, the Pulsed-TIG process can be more effective than normal GTA because of its control of the heat zone.

3.9.1 WELDING ALUMINUM

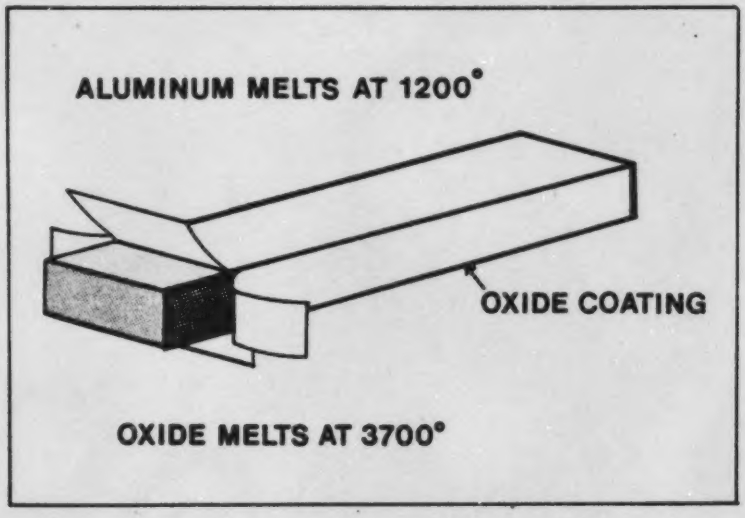
Basic research in the use of GTA has mostly been concentrated on aluminum and related alloys. It is a good idea to examine the welding properties of these metals to understand the advantages and disadvantages to the welding operator.

Aluminum is a white, soft metal, resembling tin in appearance. It is one of the most abundant constituents of the earth, found in most clays, soils, and rocks but the primary source is from bauxite ore. Aluminum alloys are classified in two groups: Wrought alloys and cast alloys. The wrought group includes those alloys designed to mill products whose final physical forms are obtained by working the metal mechanically. The casting alloy group includes those alloys where final shapes are obtained by allowing the molten metal to solidify in a mold having the desired final size and shape.

TABLE 3-5. WELDABLE METALS

Aluminums	Easily welded
Cooper base alloys	
Brasses	Difficult to weld
Bronzes	Easily welded
Copper	Easily welded
Copper nickel	Easily welded
Irons	
Cast, malleable	Weldable with precautions
Wrought iron	Weldable with precautions
Lead	Weldable with precautions
Magnesium	Easily welded
Nickel base alloys	
Inconel	Easily welded
Nickel	Easily welded
Nickel silver	Restrictive - difficult to weld
Monel	Easily welded
Precious Metals	Easily welded
Steels	
Low carbon	Easily welded
Low alloy	Easily welded
High and medium carbon	Easily welded
Alloys	Easily welded
Stainless	Easily welded
Tool	Easily welded
Titanium	Easily welded
Tungsten	Easily welded
Zinc	Restricted - difficult to weld

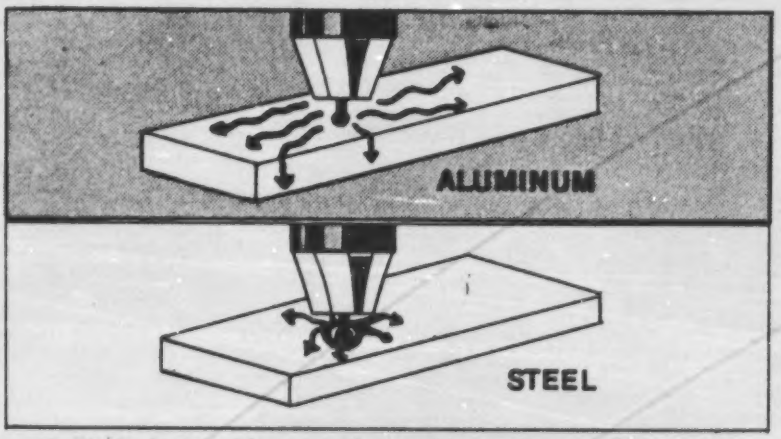
Aluminum has many unusual characteristics that influence its weldability. The first major characteristic is that aluminum (and its related alloys) has a great affinity for oxygen. Aluminum molecules combine with oxygen molecules in the air to form a tenacious, high melting point oxide that covers the surface of the metal. This characteristic is paradoxically the key to aluminum's extremely high resistance to corrosion. Pure aluminum melts at only 1200 degrees Farenheit. The oxide which protects the metal melts at 3700 degrees Farenheit. Thus, the oxide does not melt during the welding process and must be removed before the metal is welded. This process is shown in Figure 3-12.



Aluminum's tough oxide coating is broken up by the welding arc and kept from reforming by the inert gas shield.

Figure 3-12. Aluminum and Oxide Melting Points

Another characteristic in welding aluminum that makes it different from other metals is its high thermal conductivity. The heat is conducted away from the weld area three to five times faster than with steel, thus heat must be applied to the weld area faster to bring the metal up to welding temperature. This is demonstrated in Figure 3-13.



Aluminum conducts heat away from weld area three to five times as fast as steel due to its high thermal conductivity.

Figure 3-13. Thermal Conductivity

The third important welding characteristic of aluminum is that aluminum shows no color change as it is heated, even up to the melting point. The chemical composition, physical characteristics, and heat treatment of the vast array of alloys produced by manufacturers of aluminum and aluminum alloys are far too great to cover at this time. However, these manufacturers can supply information about their products. An independent study by the student of this material will increase his/her knowledge and make for a more skilled welding operator.

3.9.2 WELDING STAINLESS STEEL

Stainless steels are alloys highly resistant to all acids (except sulphuric and hydrochloric). They are also resistant to oxidation and scaling at high temperatures and retain their physical properties well under heat.

There are some 30 types of stainless steels in the ANSI Standards that can be welded in the inert atmosphere of the TIG. Direct current is preferred for welding heavy-gage stainless steels because of DC's deeper penetration and faster welding speed. Alternating current is usually preferred for light gages because of better stability. More information on types of stainless steels can be obtained from the American National Standards Institute, Washington, DC.

SECTION 4. INTRODUCTION TO LESSON PLANS

SECTION 4. INTRODUCTION TO LESSON PLANS

These lesson UNITS are designed to assist the Instructor, and to allow students to progress at their own rate of achievement. Each unit is written in an easy to understand, step-by-step procedure. By following these procedures, the student will be able to accomplish the lesson plan objective. The first four UNITS provide the introductory material necessary for pulsed-TIG welding. These UNITS are designed around lecture/discussion sessions presented by the welding instructor. The remaining UNITS are work sessions in welding techniques designed for individual student participation.

The UNIT heading indicates the lesson plan (by number) to be accomplished.

The OBJECTIVE section tells the student what should be accomplished upon the completion of the lesson.

The EQUIPMENT/MATERIALS/MACHINE SETTINGS section lists all of the equipment and technical information necessary for the completion of the UNIT. This information is provided in the form of a chart divided into sections: welding "with filler rod" and welding "without filler rod". Each of these two parts provide all of the equipment, material, and machine setting requirements for welding mild steel, stainless steel, and aluminum.

The equipment and materials generally include such items as:

a. General needs, such as clothing, welder, etc.
b. Specific equipment, such as torch, Cup, Tungsten and size.
c. What materials and filler rods are required.

The machine settings outline the pulse range and current settings to be used in the UNIT. The settings used are established for the Miller Sychrowave 300 power source. The actual settings of other machine may vary, but those provided in these lesson plans are in the general pulse range and current settings for most welding equipment. The settings are listed in the following manner:

a. Current.
b. Amperage range.
c. Amperage setting.
d. Pulsation settings, including background, pulse per second, and on-time.
e. Weld current.
f. Gas flow rate in CFH.
g. Post flow in seconds.

The PROCEDURE details the actual work to be accomplished and is set forth in a step-by-step manner and is divided into two parts: The procedures for welding various metals without filler rods, and procedures for welding those metals with filler rods. Each of these two exercises will be repeated using mild steel, stainless steel, and aluminum. The necessary equipment and machine settings will be found by locating the appropriate column in the chart of the EQUIPMENT/MACHINE SETTINGS section. (See Figure 4-1.)

Standard Equipment Standard protective clothing, helmet, gloves and safety glasses. The welding machine is: AC/DC Combination with Pulser	WITH FILLER ROD			W/O FILLER ROD		
	MILD STEEL	STAINLESS STEEL	ALUMINUM	MILD STEEL	STAINLESS STEEL	ALUMINUM
Equipment & Materials						
• TORCH						
• CUP						
• TUNGSTEN						
• SIZE						
• SHEILDING GAS						
• FILLER ROD						
• SIZE						
Machine Settings						
• CURRENT						
• AMP RANGE						
• AMP SETTING						
• PULSE SETTINGS						
• • Background						
• • Pulse/Second						
• • On Time						
• WELD CURRENT						
• GAS FLOW RATE						
• POST FLOW						

Figure 4-1. EQUIPMENT/MATERIALS/MACHINE SETTINGS

GAS TUNGSTEN ARC WELDING

MANUAL PULSE

COURSE OUTLINE - 180 HOURS

DESCRIPTION

Using a combination welder (with pulsar) will include:

a. Machine setup
b. Materials and welding conditions
c. Running beads
d. Corner welds
e. "T" - Joints
f. Butt welds
g. Lap welds
h. Basic pipe joints

OBJECTIVE

The student will learn the basic method of GTA welding. These methods will provide skills in working with mild steel, stainless steel, and aluminum in the full vertical and overhead positions using the gas tungsten arc process.

Using the light-gage material the student will be required to pass a visual and AWS guided bead test on mild steel and a visual test on stainless steel and aluminum.

Upon completion of this course the student should be able to perform production welding on mild steel, stainless steel, aluminum sheets, and limited piping. NOTE: Pipe-line welding in the 5G, 2G, and 6G fixed positions will require additional training.

BASIC TASK LISTING

a. TASK 1. Orientation/Working conditions/Safety.
b. TASK 2. Gas selection.
c. TASK 3. Machine setup - Steel/Stainless Steel.
d. TASK 4. Machine setup - Aluminum.
e. TASK 5. Filler rod/Tungsten electrode selection.
f. TASK 6. Striking the arc.
g. TASK 7. Running a bead without filler rod.
h. TASK 8. Running a bead with filler rod.
i. TASK 9. Flat fillet, single pass lap weld.
j. TASK 10. Vertical fillet, uphill lap weld.
k. TASK 11. Overhead fillet - lap weld.
l. TASK 12. Outside corner weld - flat position.
m. TASK 13. Outside corner weld - vertical position.
n. TASK 14. T - Joint weld - flat position.
o. TASK 15. T - Joint weld - vertical position.
p. TASK 16. Flat Butt weld - No bevel, flat position.
q. TASK 17. Root pass, Pipe - 1G position.

UNIT 1 - Introduction To Manual Pulsed-Tungsten Inert Gas (TIG) Arc Welding.

OBJECTIVE - Familiarize the student with the equipment, the application of the Pulsed-TIG process, safe working practices, and the proper protective clothing necessary for welding.

EQUIPMENT & MATERIALS - Combination AC/DC welder with pulsar; water-cooled welding torches; flow meter; protective clothing; and welding helmet.

LECTURE/DISCUSSION -

1. Read and discuss the definition of "TIG" welding in the Welding Encyclopedia, 17th Edition and define the relationship of pulsing to the TIG process.
2. Introduce the students to the welding machine and its various controls.
3. Briefly discuss the flow meter and shielding gases.
4. Discuss the water-cooling system and explain the differences between air-cooled and water-cooled torches.
5. Demonstrate proper protective clothing. Explain the importance of protective clothing in protecting the body from ultra violet rays and hot sparks. Discuss the proper dark lenses to be used with the welding helmet.
6. Discuss the general safety practices of the welding industry and the importance of eye protection.
7. Explain the proper use of the hand tools that are required in the preparation of practice materials, and any cleaning solvents that may be used.

CONCLUSION - A standard welding safety test may be applied at the conclusion of this unit OR the Instructor may provide a test based on the actual surroundings of where the course of instruction is given.

UNIT 2 - Shielding Gases

OBJECTIVE - Familiarize the student with the shielding gas and its purpose, the flow meter and its purpose, and the handling of gas cylinders.

EQUIPMENT AND MATERIALS - Several types of shielding gas in marked cylinders, a flow meter, and gas hoses.

LECTURE/DISCUSSION -

1. Discuss the various types of shielding gases used in the GTA process. Refer to section 3-7, Table 3-4 in the text.
2. Discuss the flow meter, its operation, and component parts. Refer to figures 3-10 and 3-11 in the text.
3. Demonstrate the proper way to hook up a flow meter to the tank and the gas lines to the welding machine. Explain the safety precautions that are used to prevent a gas leak.
4. Demonstrate the proper handling of the gas cylinder and the proper storage procedure.
5. Have the student hook up the equipment and set the flow meter to the proper settings for a simulated welding operation.
6. The students should be tested for their understanding of the shielding gas. This may be accomplished with either an oral quiz or a written test designed to suit the needs of the individual curriculum.

UNIT 3 - Machine Set-Up

OBJECTIVE - Familiarize the student with the welding machine and the proper control settings used for welding. Explain the AC/DC features as they are used for welding steel, stainless steel, and aluminum.

EQUIPMENT AND MATERIALS - Combination AC/DC welder with pulsar; torch; flow meter; and shielding gas.

LECTURE/DEMONSTRATION -

1. Give a manufacturer's description of a combination AC/DC welding machine. Refer to Appendix B in the text for detail. Discuss each control and its function.
2. Discuss the AC/DC feature and its relationship to the metals being welded.
3. Have the student set the welding controls (including the gas flow) for a pre-determined welding condition.
4. Review the trouble shooting items in the manufacturer's manual and familiarize the students with the problems that might arise in actual welding situations.
5. Discuss the safety precautions necessary for using high-voltage welding equipment.

UNIT 4 - Filler Rod/Tungsten Electrode Selection

OBJECTIVE - Familiarize the student with the various types of filler metals and how to identify these metals for use in welding. Explain the various tungsten electrodes, their proper use and care, and how to select these electrodes by color codes.

EQUIPMENT AND MATERIALS - An assortment of filler metals and tungsten electrodes.

LECTURE/DISCUSSION - Refer to section 3-5 of the text and:

1. Discuss the four types of tungsten electrodes - their size, length, and color coding. Use tables 3-1 and 3-2 in the text to illustrate. Display samples for inspection.
2. Discuss the various common welding tip problems and how to identify them. Refer to figure 3-9 in the text for examples of electrode problems.
3. Discuss filler metal and its purpose. Use section 3-6 of the text as a guide.
4. Analyze the reasons behind why it is important to select the right filler rod. Use table 3-3 of the text as a guide.
5. Have the students select the proper filler rods and tungsten electrodes for pre-determined welding conditions. Practice lesson units can be used for illustrations and evaluations.

UNIT 5 - Striking an Arc/Running Beads

OBJECTIVE - Familiarize the student with the proper handling of the welding torch in order to establish and hold a steady arc. Demonstrate the movement of the torch on low level (inter-pulse) current so that over-lapping weld nuggets are produced, then lengthened into a continuous weld bead. Explain the proper handling of filler rods to produce a continuous, reinforced weld bead using two-hand coordination.

EQUIPMENT/MATERIALS/MACHINE SETTINGS - The following table provides all of the necessary equipment, materials, and machine settings required to accomplish this unit.

Standard Equipment Standard protective clothing, helmet, gloves and safety glasses. The welding machine is: AC/DC Combination with Pulser	WITH FILLER ROD			W/O FILLER ROD		
	MILD STEEL	STAINLESS STEEL	ALUMINUM	MILD STEEL	STAINLESS STEEL	ALUMINUM
Equipment & Materials						
• TORCH	HW17	HW17	HW17	HW17	HW17	HW17
• CUP	5	5	6	5	5	6
• TUNGSTEN	2%	2%	PURE	2%	2%	PURE
• SIZE	3/32	3/32	3/32	3/32	3/32	3/32
• SHEILDING GAS	ARGON	ARGON	ARGON	ARGON	ARGON	ARGON
• FILLER ROD	OX35	308	4043			
• SIZE	1/16	1/16	3/32			
Machine Settings						
• CURRENT	DCSP	DCSP	AC	DCSP	DCSP	A.C.
• AMP RANGE	LOW	LOW	LOW	LOW	LOW	LOW
• AMP SETTING	75	70	75	70	65	70
• PULSE SETTINGS						
• • Background	40	38	30	44	40	32
• • Pulse/Second	.5	.75	.5	.5	.5	.5
• • On Time	65	60	65	69	60	72
• WELD CURRENT	40/65	40/60	35/70	44/70	40/65	36/70
• GAS FLOW RATE	20	20	20	20	20	20
• POST FLOW	12	12	12	12	12	12

PROCEDURES

THE FOLLOWING PROCEDURES ARE FOR WELDING WITHOUT FILLER ROD:

1. Obtain a 4-inch square piece of the material (16-gage for steels, 12-gage for aluminum), clean the surface and place the material in a flat position on a grounded steel surface, preparatory for welding.

   NOTE: Aluminum material requires special preparation for the removal of oxide from the surface.

2. Set the welding machine to the proper machine setting. These settings may be obtained from the EQUIPMENT/MATERIALS/ MACHINE SETTINGS Table in the beginning of this unit.

3. Grasp the torch and hold it so that the nozzle end is protruding between the index finger and the middle finger, using the thumb to hold the nozzle firmly in place. Figure 5-1 shows the proper method of holding a torch:

Figure 5-1. Proper Procedure for Holding the Welding Torch

4. Point the torch nozzle in a 20-degree angle, pointed in the direction of the weld to be made, as shown in Figure 5-2.

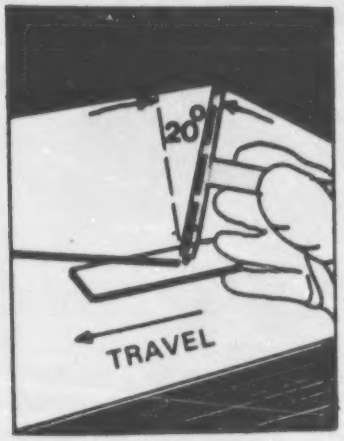


Figure 5-2. 20 Degree Angle

5. Establish the arc to form a puddle. Hold the torch motionless until the HIGH pulse time is completed, then move the torch forward during the LOW pulse time to form a series of fused areas as shown in Figure 5-3.

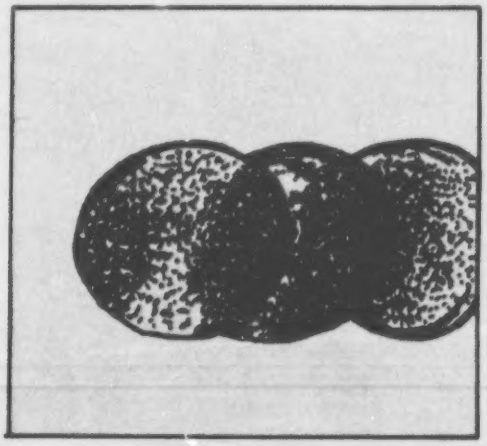


Figure 5-3. Overlapping Nuggets

6. Continue this procedure until the entire surface of the plate being welded is completely covered with a series of beads resembling overlapping nuggets. (See Figure 5-4.)

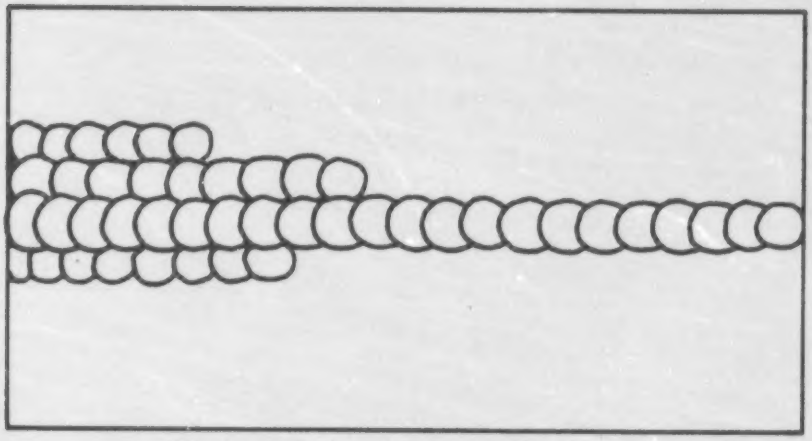


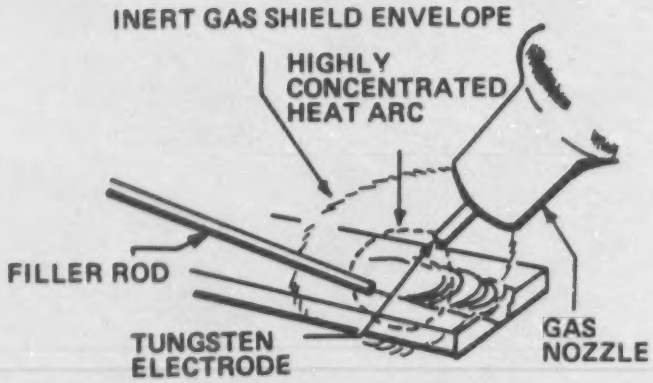
Figure 5-4. Series of Beads

7. Upon completion of this exercise, shut off the welding machine. Check your work to see how the finished beads compare. Show the work to your instructor for evaluation.

REPEAT THESE STEPS USING STEEL, STAINLESS STEEL, AND ALUMINUM.

THE FOLLOWING PROCEDURES ARE FOR WELDING WITH FILLER ROD:

8. Repeat steps 1, 2, and 3 to prepare for welding.
9. Position the torch as shown in Figures 1 and 2. Hold the filler rod at a 10 degree angle from the work piece and begin to weld, allowing the filler metal to enter the weld puddle on the pulse time cycle and moving the torch on the inter-pulse cycle.
10. Continue this procedure until the entire surface of the plate being welded is covered with a series of reinforced weld beads.
11. Upon the completion of this exercise, shut off the welding machine. Check your work to see how the reinforced weld beads compare. Show the work to your instructor for evaluation.



UNIT 6 - Lap Weld - Flat Position

OBJECTIVE - Familiarize the student with the proper handling of the welding torch for producing a quality lap-joint weld using filler rod and without filler metal.

EQUIPMENT/MATERIALS/MACHINE SETTINGS - The following chart provides all of the equipment, materials, and machine settings required to accomplish this unit.

Standard Equipment Standard protective clothing, helmet, gloves and safety glasses. The welding machine is: AC/DC Combination with Pulser	WITH FILLER ROD			W/O FILLER ROD		
	MILD STEEL	STAINLESS STEEL	ALUMINUM	MILD STEEL	STAINLESS STEEL	ALUMINUM
Equipment & Materials						
• TORCH	HW17	HW17	HW17	HW17	HW17	HW17
• CUP	5	5	6	6	6	6
• TUNGSTEN	2%	2%	PURE	2%	2%	PURE
• SIZE	3/32	3/32	3/32	3/32	3/32	3/32
• SHEILDING GAS	ARGON	ARGON	ARGON	ARGON	ARGON	ARGON
• FILLER ROD	ER 70S	308	4043			
• SIZE	1/16	1/16	3/32			
Machine Settings						
• CURRENT	DCSP	DCSP	AC.	DCSP	DCSP	AC
• AMP RANGE	LOW	LOW	HIGH	LOW	LOW	HIGH
• AMP SETTING	70	65	115	75	72	90
• PULSE SETTINGS						
• • Background	44	40	10	44	40	10
• • Pulse/Second	.5	.5	.5	.75	1	.5
• • On Time	65	60	65	65	60	65
• WELD CURRENT	44/70	42/65	60/115	45/65	42/70	60/90
• GAS FLOW RATE	20	20	20	20	20	20
• POST FLOW	12	12	12	12	12	12

PROCEDURES -

THE FOLLOWING PROCEDURES ARE FOR WELDING WITHOUT FILLER ROD:

1. Obtain two pieces of two-inch by four-inch material (16 gage for steels, 12 gage for aluminum). Clean the surface of the metal properly noting that aluminum requires special considerations.
2. Place the material on a grounded steel surface to form a lap weld, as shown in figure 6-1. Set the welding machine to the proper settings and tack weld each end.

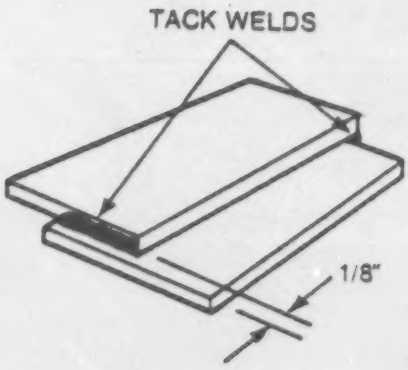


Figure 6-1. Proper Tack Welding

3. Grasp the torch in the manner previously instructed and position in a 80 to 85 degree angle to the work and 10 degrees

in the direction of the weld. Establish the arc, form a puddle, and then move along the joint melting off the edge of the top plate pushing the metal downward to form a bead.

4. Turn the piece over and complete the other side in the same manner.
5. Upon completion of this exercise, shut off the welding machine. Check your work to see how the finished beads compare. Show the work to your instructor for evaluation.

REPEAT THESE STEPS USING STEEL, STAINLESS STEEL, AND ALUMINUM

THE FOLLOWING PROCEDURES ARE FOR WELDING WITH FILLER ROD:

6. Repeat steps 1 and 2.
7. Grasp the torch as previously instructed, positioned in an 80 to 85 degree angle to the work and 15 to 20 degrees in the direction of the weld. Position the filler metal rod at a 10 degree angle from the work piece with a side angle of 5 to 10 degrees. See figure 6-2 for an example.

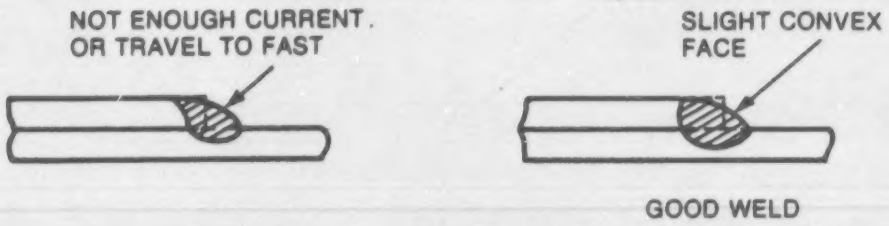


Figure 6-2. Welding With Filler Rod

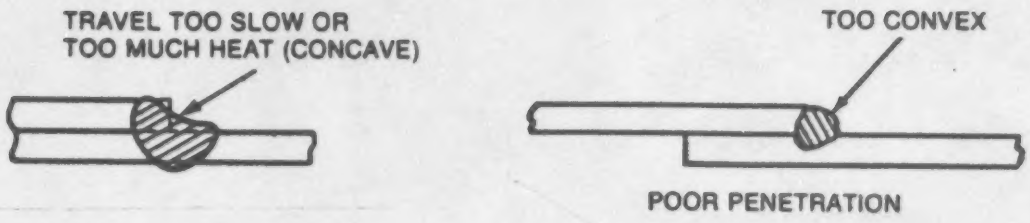


Figure 6-2. Welding With Filler Rod (Continued)

8. Establish the arc and form a puddle. Add the filler metal to the puddle while the arc is in the pulse action. NOTE: It may not be necessary to manipulate the filler rod depending on the size of the bead desired.
9. The finished bead face should be flat or slightly convex with good fusion into the base metal. Turn the piece over and complete the other side, comparing the finished beads.
10. Upon completion of the exercise, shut off the welding machine and have the instructor evaluate your work.

REPEAT THESE STEPS USING STEEL, STAINLESS STEEL, AND ALUMINUM

UNIT 7 - Outside Corner Weld - Flat Position and Vertical Position

OBJECTIVE - Familiarize the student with the torch and filler rod manipulations for outside corner welds in the flat position without and with filler metal, and in the vertical position with filler metal.

EQUIPMENT/MATERIALS/MACHINE SETTINGS - The following chart provides all of the equipment, materials, and machine settings necessary to complete this UNIT.

Standard Equipment Standard protective clothing, helmet, gloves and safety glasses. The welding machine is: AC/DC Combination with Pulser	WITH FILLER ROD			W/O FILLER ROD		
	MILD STEEL	STAINLESS STEEL	ALUMINUM	MILD STEEL	STAINLESS STEEL	ALUMINUM
Equipment & Materials						
• TORCH	HW17	HW17	HW17	HW17	HW17	HW17
• CUP	5	5	6	5	5	6
• TUNGSTEN	2%	2%	PURE	2%	2%	PURE
• SIZE	3/32	3/32	3/32	3/32	3/32	3/32
• SHEILDING GAS	ARGON	ARGON	ARGON	ARGON	ARGON	ARGON
• FILLER ROD	ER70S	308	4043			
• SIZE	1/16	1/16	3/32			
Machine Settings						
• CURRENT	DCSP	DCSP	AC	DCSP	DCSP	AC
• AMP RANGE	LOW	LOW	HIGH	LOW	LOW	HIGH
• AMP SETTING	75	60	80	70	65	90
• PULSE SETTINGS						
• • Background	25	30	10	25	30	10
• • Pulse/Second	.5	.75	.5	.5	.75	.5
• • On Time	55	60	55	50	60	55
• WELD CURRENT	20/75	28/60	40/90	22/70	32/65	55/90
• GAS FLOW RATE	20	20	20	20	20	20
• POST FLOW	12	12	12	12	12	12

PROCEDURES

THE FOLLOWING PROCEDURES ARE FOR OUTSIDE CORNER WELDS IN THE FLAT POSITION WITH FILLER ROD:

1. Obtain 2 pieces of 2-inch by 4-inch, 16-gage material (12-gage for aluminum). Set up the welder using the settings on the settings chart and assemble the pieces as shown in figure 7-1.

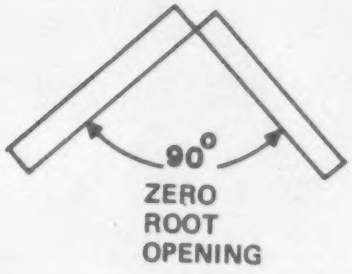


Figure 7-1

2. Tack weld each end as shown in figure 7-2. Each tack should be approximately one-half inch long.

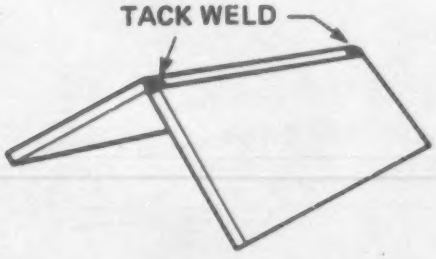


Figure 7-2

3. Start welding as shown in figure 7-3. Move the torch in a steady motion during the inter-pulse cycles. Complete the weld using the extended edge of the metal plate as the filler metal.

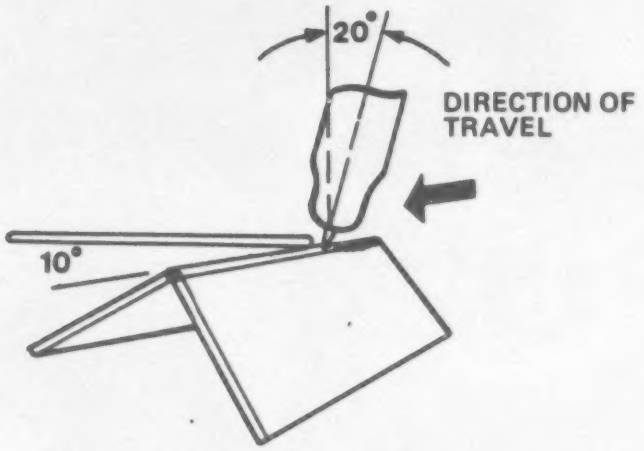


Figure 7-3

4. Check the weld upon completion for appearance and penetration (see figure 7-4 for example). Show your work to the instructor for evaluation.

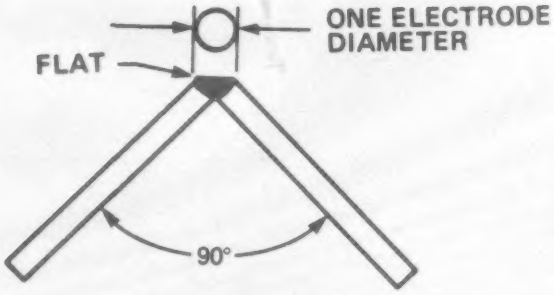


Figure 7-4

REPEAT THESE STEPS USING MILD STEEL, STAINLESS STEEL, AND ALUMINUM.

THE FOLLOWING PROCEDURES ARE FOR OUTSIDE CORNER WELDS IN THE FLAT POSITION WITHOUT FILLER RODS:

5. Repeat procedures 1 and 2. Assemble the material as shown in figure 7-5 and tack weld as shown in figure 7-6.

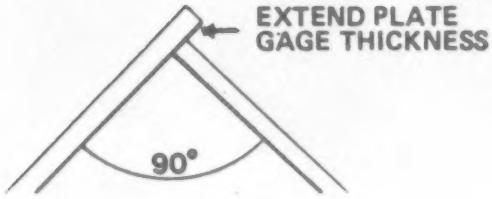


Figure 7-5

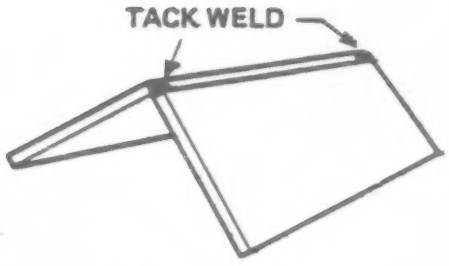


Figure 7-6

6. Set the welding machine to the appropriate settings on the settings chart. Hold the torch in the proper manner and the filler rod at a 10 degree angle from the work piece. Start the weld as shown in figure 7-7.

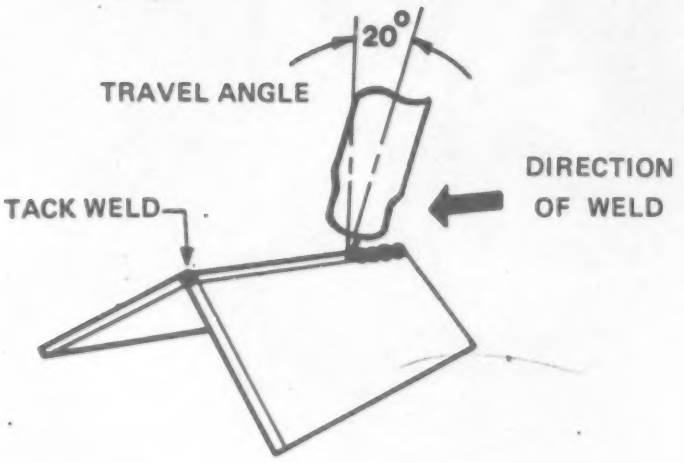


Figure 7-7

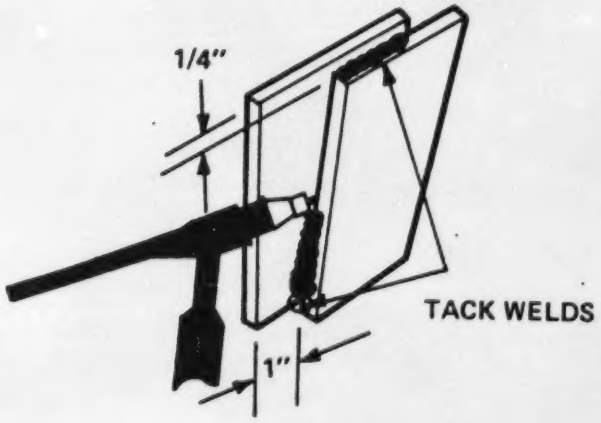
7. Complete the weld and examine for appearance as shown in figure 7-8. Show the work to your instructor for evaluation.

Figure 7-8

REPEAT THESE STEPS USING MILD STEEL, STAINLESS STEEL, AND ALUMINUM.

THE FOLLOWING PROCEDURES ARE FOR OUTSIDE CORNER WELDS IN THE VERTICAL POSITION WITH FILLER RODS:

8. Repeat procedures 1 and 2. Hold the torch in the proper manner with the filler rod positioned 5-10 degrees from the work piece. Start the weld as shown in figure 7-9.



9. Complete the weld and inspect for bead appearance and penetration. Show the work to your instructor for evaluation.

REPEAT THESE STEPS USING STEEL, STAINLESS STEEL, AND ALUMINUM.

UNIT 8 - T-Joint Weld in the Flat Position and the Uphill Vertical Position

OBJECTIVE - Familiarize the student with the proper way to hold the torch and filler rod in order to complete an acceptable fillet weld in the flat position and in the uphill vertical position.

EQUIPMENT/MATERIALS/MACHINE SETTINGS - The following chart provides all of the equipment, materials, and machine settings necessary to complete this UNIT.

Standard Equipment Standard protective clothing, helmet, gloves and safety glasses. The welding machine is: AC/DC Combination with Pulser	Flat Position			Vertical Position		
	MILD STEEL	STAINLESS STEEL	ALUMINUM	MILD STEEL	STAINLESS STEEL	ALUMINUM
Equipment & Materials						
• TORCH	HW17	HW17	HW 17	HW 17	HW17	HW 17
• CUP	5	5	6	6	5	6
• TUNGSTEN	2%	2%	PURE	2%	2%	PURE
• SIZE	3/32	3/32	3/32	3/32	3/32	3/32
• SHEILDING GAS	ARGON	ARGON	ARGON	ARGON	ARGON	ARGON
• FILLER ROD	0X35	308	4043	0X35	308	4043
• SIZE	3/32	3/32	3/32	3/32	3/32	3/32
Machine Settings						
• CURRENT	DCSP	DCSP	AC	DCSP	DCSP	AC
• AMP RANGE	HIGH	HIGH	HIGH	HIGH	LOW	HIGH
• AMP SETTING	130	120	115	80	70	90
• PULSE SETTINGS						
• • Background	40	30	10	40	33	10
• • Pulse/Second	.5	.75	.5	.5	.75	.5
• • On Time	60	60	65	60	60	65
• WELD CURRENT	44/125	40/115	50/130	40/80	38/70	40/90
• GAS FLOW RATE	20	20	20	20	20	20
• POST FLOW	12	12	12	12	12	12

PROCEDURES

THE FOLLOWING PROCEDURES ARE FOR T-JOINT WELDS IN THE FLAT POSITION

1. Obtain 2 pieces of 2-inch by 4-inch, 16-gage material (12-gage for aluminum). Assemble the material to form a T-joint as shown in figure 8-1. Clean all material then tack weld, each tack weld being approximately 1/2-inch in length.

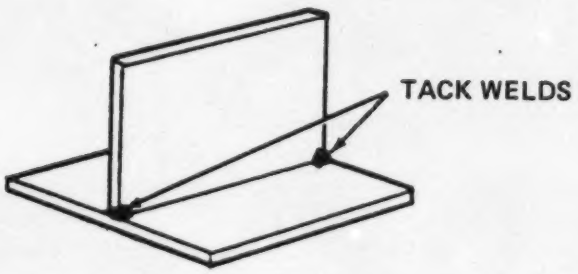


Figure 8-1

2. Set the welding machine at the proper settings and begin to weld the assembly in the manner shown in figure 8-2, holding the torch 20-degrees in the direction of travel and at a 50-degree angle side angle. Move the torch during inter-pulse time in a steady movement to complete the weld bead. The filler rod should be held at a 10-degree angle from the flat plate and positioned at the top edge of the weld puddle to prevent undercutting.

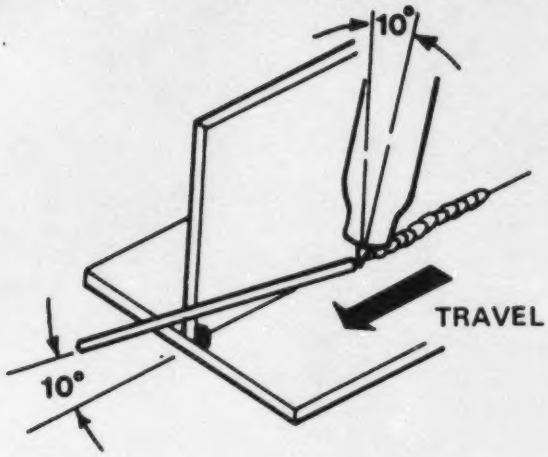


Figure 8-2

3. Complete the weld and check for bead appearance and undercut. The bead should be approximately 3 diameters of the tungsten electrode used. (See figure 8-3.) Show the work to your instructor for evaluation.

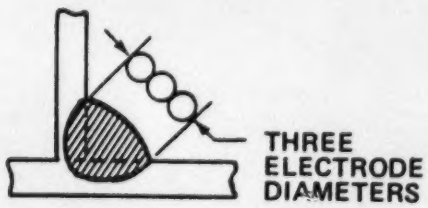


Figure 8-3

REPEAT THESE STEPS USING STEEL, STAINLESS STEEL, AND ALUMINUM

THE FOLLOWING PROCEDURES ARE FOR T-JOINT WELDS IN THE UPHILL VERTICAL POSITION

4. Repeat step 1. Place the work piece in a vertical position for welding.

5. Set the welding machine to the proper settings and start the weld at the bottom of the joint, welding in the uphill method. Hold the filler rod 10-degrees to the plate and allow it to feed into the center of the molten nugget. Hold the torch so that the tungsten electrode is pointed upward, approximately 20-degrees below the center axis. (See figure 8-4.)

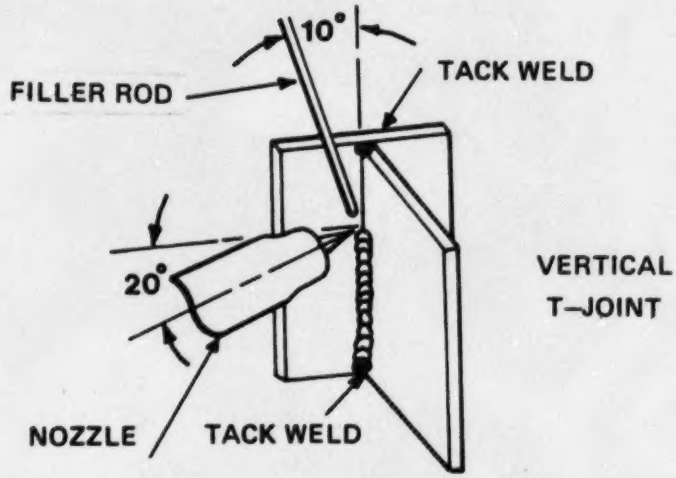


Figure 8-4

6. Complete the weld by moving the torch upward in a steady motion during the inter-pulse cycle. Check for bead appearance and undercut. The weld nuggets should be evenly spaced and the bead width should be as shown in figure 8-5. Turn off the welding machine and show your work to the instructor for evaluation.

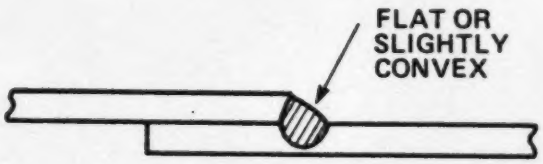


Figure 8-5

REPEAT THESE STEPS USING STEEL, STAINLESS STEEL, AND ALUMINUM

UNIT 9 Butt Weld - Flat Position, No Bevel

OBJECTIVE - Familiarize the student with the butt weld. Make an acceptable butt weld in the flat position with 100% penetration.

EQUIPMENT/MATERIALS/MACHINE SETTINGS - The following chart provides all of the equipment, materials, and machine settings necessary to complete this UNIT.

Standard Equipment Standard protective clothing, helmet, gloves and safety glasses. The welding machine is: AC/DC Combination with Pulser	WITH FILLER ROD			W/O FILLER ROD		
	MILD STEEL	STAINLESS STEEL	ALUMINUM	MILD STEEL	STAINLESS STEEL	ALUMINUM
Equipment & Materials						
• TORCH	HW17	HW17	HW17			
• CUP	5	5	5			
• TUNGSTEN	2%	2%	PURE			
• SIZE	3/32	3/32	3/32			
• SHEILDING GAS	ARGON	ARGON	ARGON			
• FILLER ROD		308	4043			
• SIZE	1/16	1/16	3/32			
Machine Settings						
• CURRENT	DCSP	DCSP	AC			
• AMP RANGE	LOW	LOW	HIGH			
• AMP SETTING	75	68	90			
• PULSE SETTINGS						
• • Background	38	40	5			
• • Pulse/Second	.5	1	.5			
• • On Time	70	60	03			
• WELD CURRENT	38/75	44/60	20/90			
• GAS FLOW RATE	20	20	20			
• POST FLOW	12	12	12			

PROCEDURES -

1. Obtain 2 pieces of 3-inch by 6-inch 16-gage material (12-gage for aluminum) and prepare the surfaces for welding. (Aluminum will need special preparation.)

2. Place the work piece on a flat, grounded surface and set up as shown in Figure 9-1. Seperate the plates at the edge to be welded by 1/16-inch to provide a root opening for penetration. Tack weld each end to secure this root opening.

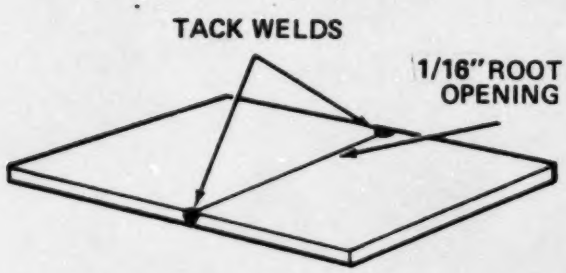


Figure 9-1

3. Start the weld by using the proper filler metal and holding the rod no more than 10-degrees above the surface of the work piece. Begin running a bead using filler metal as shown in UNIT 5.

4. Complete the weld along the entire length of the butt.

5. Upon completion check the weld for bead appearance and penetration. Show the work to your instructor for evaluation.

REPEAT THESE STEPS USING STEEL, STAINLESS STEEL, AND ALUMINUM.

UNIT 10 - Pipe Welding - Root Pass in the 1G Position (1/4 Turn)

OBJECTIVE - Familiarize the student with standard joint specifications, assembly procedures, and how to manipulate the welding torch and filler rod in order to complete an acceptable root bead.

EQUIPMENT AND MATERIALS - The following equipment and materials are required to complete this UNIT:

Combination AC/DC Welder with pulsar; Protective clothing and eyewear; 2 sections of 8" schedule 40 steel pipe (pre-beveled); HW 18 torch with 2% thor. tungsten filler rod; 3/32" AWS E-70S-3; argon shielding gas

ASSEMBLY PROCEDURE -

1. Discuss the weld joint definitions and standard joint specifications to be used in this exercise. (See figure 10-1.)

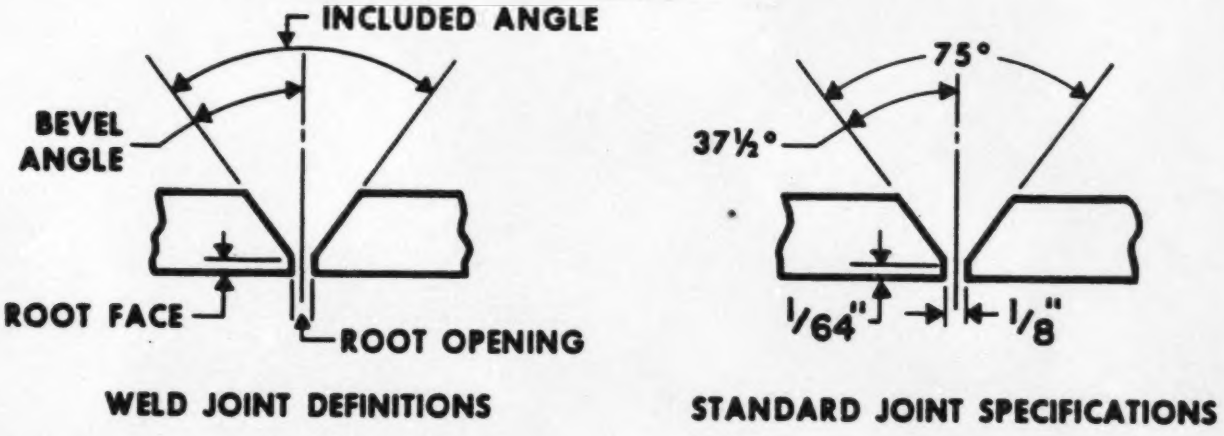


Figure 10-1

2. Check the bevel surfaces of the pipe nipples. The surface should be free of burrs and must have no oil, grease, moisture, or rust on it. Place the assembly on the work table and place a 1/8" wire, bent in a "V" shape, between the pipe sockets as a spacer. (See figure 10-2.)

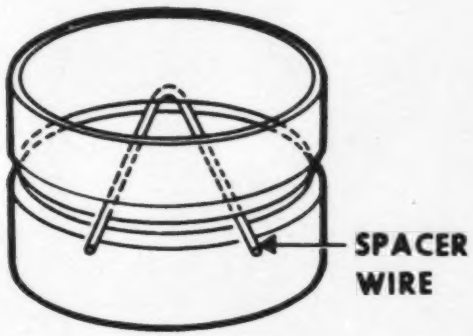


Figure 10-2

3. Place 1/2" tack welds between the spacer wire using a filler rod as shown in figure 10-3.

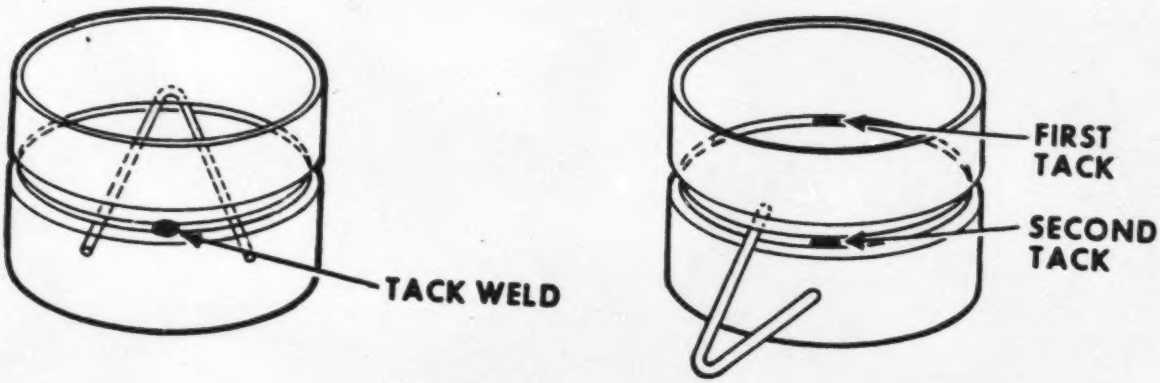


Figure 10-3

The tack weld should penetrate well into the root and sides of the joint. The back side of the root bead should have no more than 1/16" crown as shown in figure 10-4.

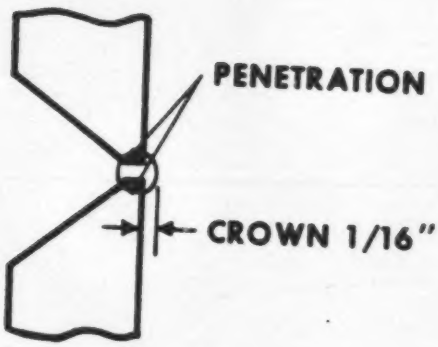


Figure 10-4

WELDING PROCEDURE -

4. Secure the assembly in a horizontal position as shown in figure 10-5 and set the welder to the following machine settings:

Current DCSP

AMP Range HIGH AMP Setting 105

Pulse Setting

Back Ground 15

Pulse Per Second .5

On Time 58

Weld Current 70/105

Gas Flow Rate 20

Post Flow Rate 12

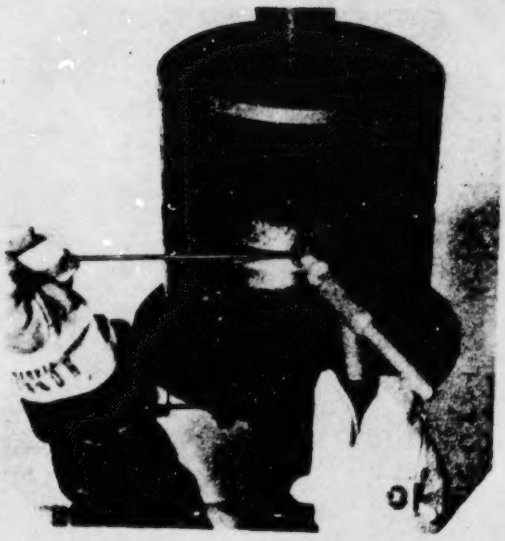


Figure 10-5

5. While holding the end of the filler rod lightly at the leading edge of the weld puddle (as shown in figure 10-6), move the torch upwards, starting at the 3 o'clock position, on the inter-pulse cycle and slightly move the torch side to side on the pulse cycle (see figure 10-7). This side to side movement will flatten the bead and penetrate the sides of the pipe. It is important that the operator keep all movements precise and at an even rate with the pulse cycle.

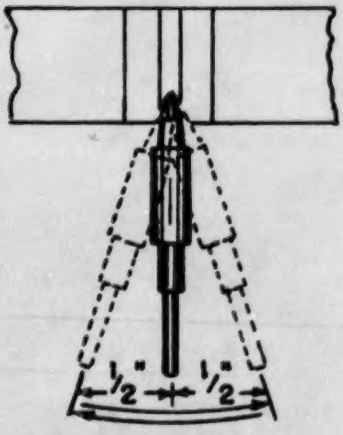


Figure 10-6

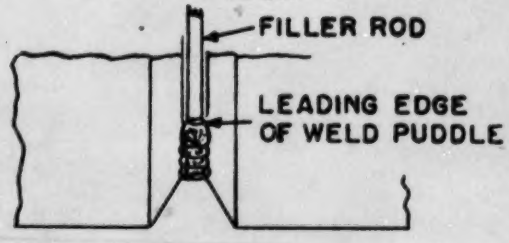


Figure 10-7

6. Complete the first quarter-section weld and then rotate the work piece as shown in figure 10-8 to complete all 1/4 weld segments into a continuous root weld.

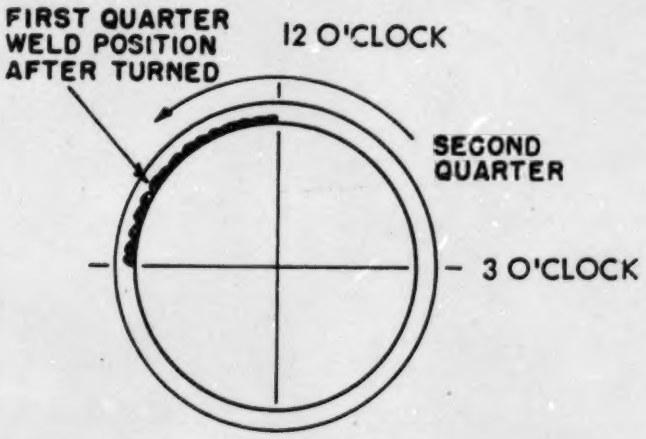


Figure 10-8

7. Upon completion of the weld, shut off the welding machine. Examine the bead and compare it to that shown in figure 10-9. Show your work to the instructor for evaluation.

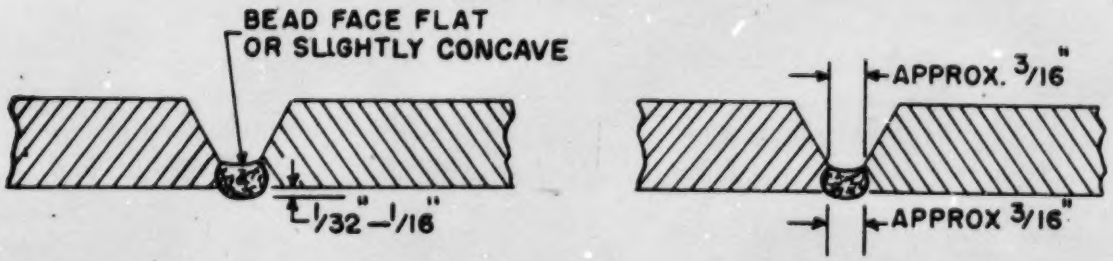


Figure 10-9

SUMMARY

SUMMARY

This project in pulsed-TIG welding was undertaken to provide vocational training in an important new welding tool. Pulsed-TIG welding reduces the training curve normally associated with teaching welding. The purpose of this project is to develop a short course to teach the fundamentals of this new welding process. Although not a detailed course in welding, it is intended that this curriculum will provide the job skills necessary for entry into the welding profession in less time than in normal vocational welding instruction.

PROJECT HISTORY

In my research effort I contacted the National Network for Curriculum Coordination in Vocational and Technical Education (a USOE sponsored activity). I recieved 16 replies, all of which indicated that these sources had no information available on pulsed-TIG welding. I began my research from sources known to me from my professional welding background, logging over 500 hours to obtain written data, engineering and technical reports, and to develop the procedures used to write the

curriculum text. Many additional hours were spent working with the equipment to gather the necessary technical detail to formulate the lesson plans. My editor/technical coordinator and technical advisor worked closely with me at this time coordinating the materials gathered for this presentation.

I visited the Hobart Welders Training and Technical Center in Troy, Ohio to obtain first-hand working knowledge of the equipment. They were not teaching a seperate pulsed-TIG course but were using the procedure along with TIG welding for instructing welders in mid-western power plants. (The Hobart Welding Engineer is now in the process of developing a book on pulsed-TIG welding.)

I also visited the DuPont Company in Deepwater, New Jersey and the DeLave Company in Trenton, New Jersey to discuss how these companies use pulsed-TIG technology. Thse companies use pulsed-TIG primarily in pipe welding and have expressed an interest in vocationally-trained operators of limited skills (trained only in pulsed-TIG) to help meet their growing needs for pulsed-TIG welding applications.

FUTURE APPLICATIONS

The pulsed-TIG process, as presented in my text, will be introduced to seniors in my welding class in the fall of 1979. The pulsed-TIG text will be used in conjunction with the existing manual-TIG program that I have previously developed. I am currently working with selected students in my current junior class to evaluate the lesson plans that have been developed.

The Adult Division of the Atlantic County Vocational-Technical School has expressed an interest in offereing the pulsed-TIG process along with a special TIG welding course in the Fall Semester. The Adult Division feels that such a course would attract welders who desire to become pipe welders, and also novices who want to learn welding but have little experience in the field. They feel that this curriculum would present a good opportunity for minority and underprivlidged students.

CONCLUSIONS

This curriculum has proven to be an effective teaching tool when presented to junior-level vocational students. I found that my students were able to grasp the concepts of pulsed-TIG welding and become effective operators with little or no additional information besides what is offered in my text.

I did not, however, have sufficent opportunity to evaluate the effectiveness of the curriculum for teaching novice welders, those with very little or no experience. I still feel that this area should be further explored, evaluated, and developed. I feel that pulsed-TIG welding can be a useful part of adult vocational education and help alliviate some of the unemployment problem in Atlantic County. Future efforts should use this text as a core to develop actual training programs in the area defined above.

APPENDIX A. USERS GUIDE FOR MILLER SYNCROWAVE 300

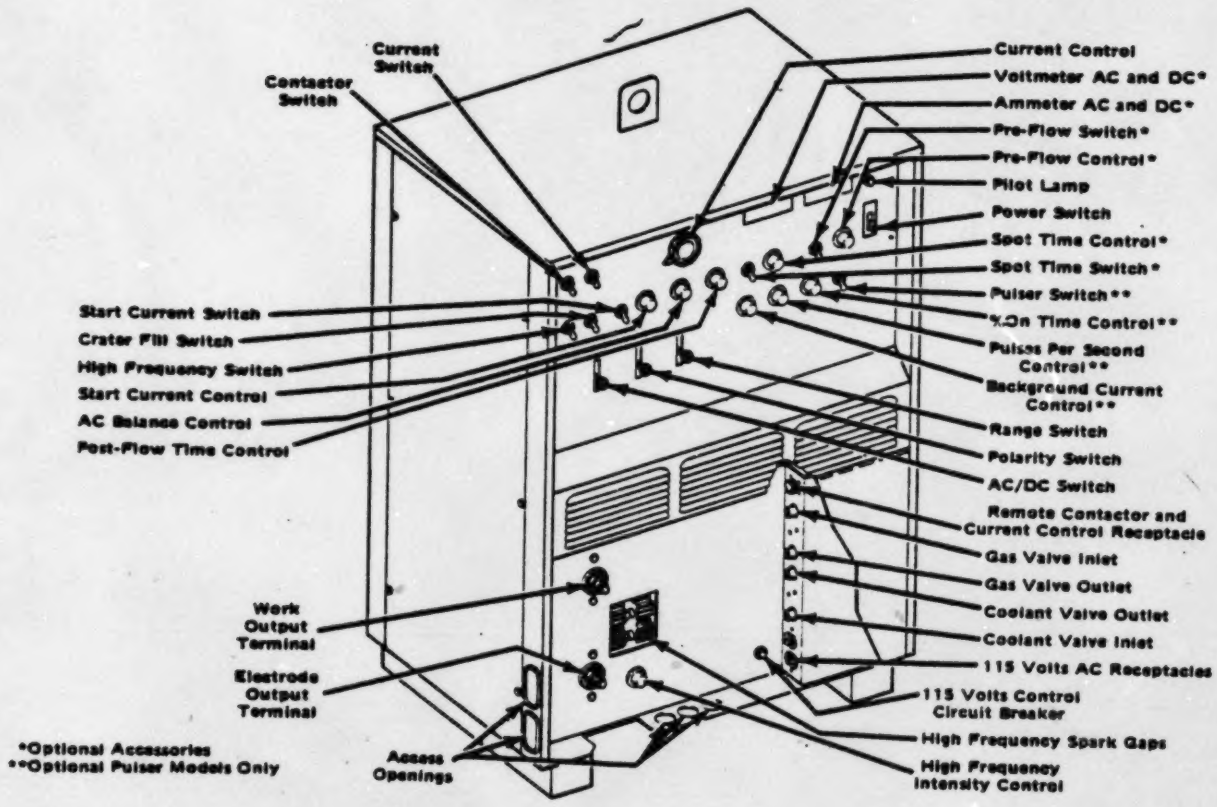


Figure A-1. **Front Panel View (300 Ampere Model Illustrated)**

A.1 POWER SWITCH (Figure A-1)

CAUTION

Even though the POWER switch is in the OFF position and the welding power source is apparently electrically shut down, electrical input power is still present on all circuitry up to the POWER switch. To completely cut off all electrical power to the welding power source, it will be necessary to place the line disconnect switch in the OFF position or to remove the line fuses.

Placing the POWER switch in the ON position will energize the welding power source fan and control circuitry and place the welding power source in a ready-to-weld status. Placing the POWER switch in the OFF position will shut the welding power source down.

A.2 CURRENT CONTROL (Figure A-1)

A. Range Switch (300 Ampere Models Only)

The RANGE switch provides the capability of selecting from two ac or dc coarse amperage ranges: HIGH and LOW. The amperage range of each switch position is provided on the welding power source nameplate. If the amperage desired should fall in the overlapping area of two ranges, it is recommended that the lower of the two ranges be used, as better fine amperage adjustment is obtained in the lower of the two ranges.

Fine amperage adjustment within the coarse range selected is provided by the CURRENT CONTROL. This function is explained below.

IMPORTANT

Do not change the position of the RANGE switch while welding or under load, as this will cause the contacts of the switch to arc. Arcing across the contacts will cause the contacts to become pitted and thereby eventually to become inoperative.

B. Current Control (300 Ampere Models Only)

NOTE

The contacts of the CURRENT CONTROL are of the continuous contact type, thereby making it possible to adjust the amperage output while welding.

The CURRENT CONTROL provides a means of selecting the exact amperage desired within the entire range being used.

Rotating the control in a clockwise direction increases the amperage output.

The scales surrounding the CURRENT CONTROL are calibrated in amperes ac or dc, depending on the position of the AC/DC switch. Ensure that the scale being read corresponds to the position of the RANGE switch.

C. Current Control (500 Ampere Models Only)

The CURRENT CONTROL is a ten-turn potentiometer that is used to control the current output of the welding power source. This control will adjust the output within a range of 25 to 625 amperes. The scale surrounding the control is calibrated from 0-1000. The numbers represent the position of the potentiometer and should not be misconstrued as an actual current value. The current output may be determined from the meter on the front panel or from an external meter. The scale is provided to enable the operator to obtain repeatable outputs.

NOTE

The contacts of the CURRENT CONTROL are of the continuous contact type, thereby making it possible to adjust the amperage output while welding.

D. Current Switch

If a remote current control is to be used, make connections from the remote current control to the REMOTE CONTACTOR AND CURRENT CONTROL receptacle

When remote control of the current is desired, it is essential that the CURRENT switch be placed in the REMOTE position. Likewise, if a remote current control is not to be utilized, the switch must be in the PANEL position. When in the PANEL position, only the CURRENT CONTROL on the front panel will control the amperage.

E. Polarity Switch

The POLARITY switch provides a means of selecting either dc-straight or dc-reverse polarity without having to change the output cable connections.

Placing the POLARITY switch in the STRAIGHT position causes the ELECTRODE output terminal to be of negative polarity and the WORK output terminal to be of positive polarity. Conversely, if the POLARITY switch is placed in the REVERSE position, the ELECTRODE output terminal is of positive polarity and the WORK output terminal is of negative polarity. The POLARITY switch has no effect on the welding operations when the AC/DC switch is in the AC position.

IMPORTANT

Do not change the position of the POLARITY switch while welding or under load, as this will cause the contacts of the switch to arc. Arcing across the contacts will cause the contacts to become pitted and thereby eventually to become inoperative.

F. AC/DC Switch

The AC/DC switch provides a means of selecting whether the welding power source output will be alternating current (ac) or direct current (dc).

IMPORTANT

Do not change the position of the AC/DC switch while welding or under load as this will cause the contacts of the switch to arc. Arcing across the contacts will cause the contacts to become pitted and thereby eventually to become inoperative.

A.3 START CURRENT CONTROL (Figure A-1)

The START CURRENT control facility in this welding power source permits the operator to select an amperage setting for arc initiation which is different from the setting of the CURRENT CONTROL. The starting current selected is in effect for approximately the first second of the weld. After this time period, the weld current goes to the setting of the CURRENT CONTROL.

A. Start Current Switch

A two-position toggle switch is provided to determine whether or not the start circuit is functional. Placing the START CURRENT switch in the ON position will make the START CURRENT control operative. The OFF position makes the START CURRENT control inoperative thereby causing the weld current to go immediately to the setting of the CURRENT CONTROL at arc initiation.

B. Start Current Control

The START CURRENT control provides fine current selection within the minimum to maximum capabilities of the range being used for the initial one-second time period of the weld. After this initial time period, the weld current either slopes up or down to the setting of the CURRENT CONTROL.

The scale surrounding the START CURRENT control is calibrated arbitrarily and should not be misconstrued as an amperage or voltage reading. It is recommended that meters be read whenever it is necessary to know the amperage and voltage output.

A.4 CONTACTOR SWITCH (Figure A-1)

The contactor control circuitry in this welding power source enables the operator to remotely control the availability of weld output from the work station provided that the POWER switch is in the ON position.

If a remote contactor control is to be used, make connections to the REMOTE CONTACTOR AND CURRENT CONTROL receptacle as instructed in Section 3-5.

If a remote contactor control is not to be used, place the CONTACTOR switch in the STANDARD position. When in the STANDARD position, weld output is available as soon as and for as long as the POWER switch is ON.

When a remote contactor control is to be used, the CONTACTOR switch must be placed in the REMOTE position. With a remote contactor control, weld output is available whenever, and for as long as, the remote contactor control switch is closed.

CAUTION

Whenever the CONTACTOR switch is in the STANDARD position, open-circuit voltage will be present at the secondary terminals as long as the POWER switch is ON.

A.5 REMOTE CONTACTOR CONTROL SWITCH

Remote control of the solid-state contactor in the welding power source can be achieved through use of the supplied maintained-contact rocker switch. The switch has been designed to be taped to the electrode holder handle.

See Section 3-5 and the instructions supplied with the switch for installation procedures. When installed, the switch provides fingertip control of the contactor circuit by the operator while welding as long as the CONTACTOR CONTROL switch is in the REMOTE position.

A.6 HIGH FREQUENCY SWITCH (Figure A-1)

CAUTION

Ensure that the HIGH-FREQUENCY switch is in the OFF position before performing Shielded Metal-Arc Welding (SMAW). The attempted use of high frequency to establish an arc with a stick electrode could cause an arc to form between the electrode holder and the operator, which could result in serious injury.

The HIGH-FREQUENCY switch provides three positions which determine the length of time the high frequency is either on or off.

A. Start Position

When in the START position, high frequency is present at the welding electrode when the arc is initiated and for approximately 2.5 seconds thereafter. Once the 2.5 second time interval has expired, and even though the remote contactor control switch is closed, the high-frequency is deenergized. High-frequency is present again automatically whenever the arc requires high-frequency.

B. Continuous Position

When the HIGH-FREQUENCY switch is in the CONTINUOUS position, high frequency will be present whenever weld current is available at the output terminals.

If the CRATER FILL switch is in the OUT position, high frequency will be shut down when the remote control switch is released.

If the CRATER FILL switch is in the IN position and the remote control switch is released, high frequency will continue to be present until the end of the crater fill period.

C. Off Position

High frequency is not available when in the OFF position, even if the remote contactor control switch is closed.

A.7 COOLANT-GAS POST-FLOW CONTROL (Figure A-1)

An adjustable 6 to 60 second coolant-gas POST-FLOW TIME control is provided for controlling the period of time shielding gas and coolant is allowed to flow after the arc is extinguished. The POST-FLOW TIME control governs the operation of a post-flow timer within the welding power source.

Rotating the control in a clockwise direction increases the post-flow time. The scale surrounding the POST-FLOW TIME control is calibrated in seconds to aid in the selection of a post-flow time period suited to the individual welding operation.

As soon as the arc has been extinguished, the post-flow timer begins to time out the selected period of post-flow time. Once the timer has timed out, the gas and coolant valves close and thereby cut-off shielding gas and coolant flow. The timer automatically resets and is ready for another weld cycle.

NOTE

The post-flow timer is automatically disabled whenever the CONTACTOR switch is in the STANDARD position and the remote contactor control is disconnected from the welding power source, despite the position of the POST-FLOW TIME control. To prevent the gas/coolant valves from being operable when the Shielded Metal-Arc Welding (SMAW) process is used, ensure that the CONTACTOR switch is in the STANDARD position and the remote contactor control is disconnected from the welding power source.

A.8 CRATER FILL SWITCH (Figure A-1)

The CRATER FILL switch provides a means for selecting whether the crater-fill circuit is operative or not. Placing the CRATER FILL switch in the IN position allows the crater-fill circuit to be operative, whereas placing the switch in the OUT position disables the crater-fill circuitry.

The crater-fill circuitry provides a gradual decline of weld current from the selected weld current to a low level of weld current. This weld output declination occurs over an approximate five-second time interval. By utilizing the crater-fill circuit in the Gas Tungsten-Arc Welding (GTAW) process, better weld-puddle solidification at the end of the weld is achieved.

Whenever the CRATER FILL switch is in the IN position, the CURRENT switch should be placed in the PANEL position and the CONTACTOR switch should be placed in the REMOTE position.

If the START CURRENT switch is in the ON position and the CRATER FILL switch is in the IN position, about seven seconds must be allowed between the time the remote contactor control switch is opened and the time the remote contactor control switch is again closed. This time delay is to assure proper reset of the start control circuitry.

When utilizing the crater-fill mode, ensure that the POST-FLOW TIME control is adjusted to a time longer (8-10 seconds) than the crater-fill time. If the POST-FLOW TIME control is adjusted to a time less than 5 seconds, the shielding gas and coolant flow ceases before the end of the crater-fill current decline.

NOTE

The CRATER-FILL switch should be placed in the OUT position when employing the Shielded Metal-Arc Welding (SMAW) process.

A.9 AC BALANCE CONTROL (Figures A-1 & A-2)

The AC BALANCE control alters the basic Gas Tungsten-Arc Welding (GTAW) output wave shape to provide either better cleaning action or deeper penetration. Rotating the control clockwise towards the MAX. PENETRATION position yields deeper penetration. Rotating the control counterclockwise towards the MAX. CLEANING position yields more cleaning action of the workpiece - a definite asset when welding oxide-forming materials such as aluminum or magnesium.

When the control is in the BALANCED position, the basic weld output wave shape is unaltered and a compromise between good penetration and good cleaning action will be achieved.

NOTE

The contacts of the AC BALANCE control are of the continuous type, thereby making it possible to adjust this control while welding.

The scale surrounding the AC BALANCE control is calibrated arbitrarily and should not be misconstrued as an amperage or voltage reading. It is recommended that meters be read whenever it is necessary to know the amperage and voltage output.

NOTE

When employing the DC Gas Tungsten-Arc Welding (GTAW) process, the AC BALANCE control should be rotated to the BALANCED position.

IMPORTANT

For the AC BALANCE control to work properly, it is required that the electrode and work welding cables be connected to the proper terminals on the welding power source (electrode cable to the ELECTRODE terminal and work cable to the WORK terminal). The POLARITY switch is inoperative in the AC mode and cannot be used to correct reversed connections. If the cables are reversed, the AC BALANCE control will work backwards.

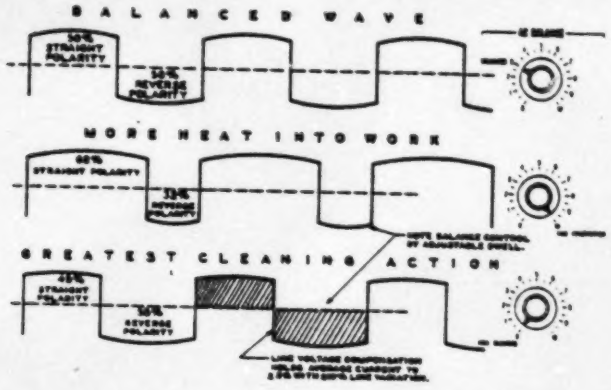


Figure A-2 Square Wave Function Of The AC Balance Control

A.10 PILOT LAMP (Figure A-1)

The pilot lamp, when illuminated, indicates that the welding power source is energized.

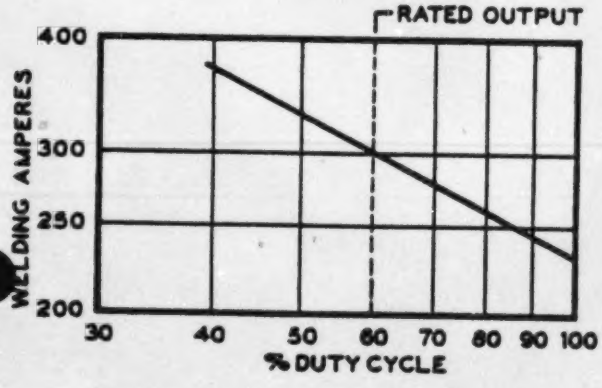
A.11 HIGH-FREQUENCY INTENSITY CONTROL (Figure A-1)

The HIGH-FREQUENCY INTENSITY control governs the strength of the high frequency. Rotating the control in a clockwise direction increases the intensity of the high frequency.

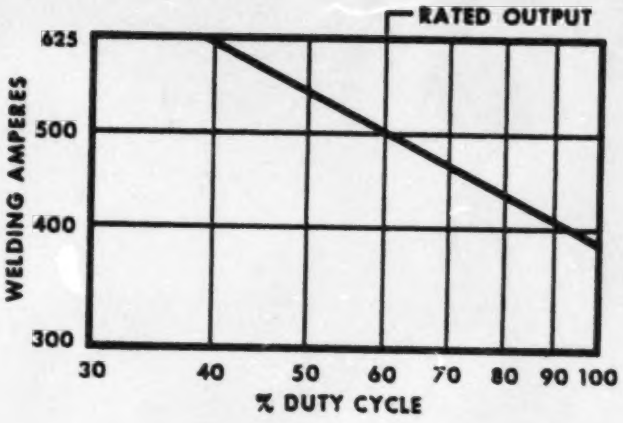
NOTE

As the high-frequency intensity is increased, the possibility of interfering with local electronic apparatus, especially communication equipment, also increases. It is recommended that the HIGH-FREQUENCY INTENSITY control be set at as low a position as practical in order to avoid such interference.

A.12 DUTY CYCLE (Figure A-3)



300 Ampere Models



500 Ampere Models

Figure A-3. Duty Cycle Charts

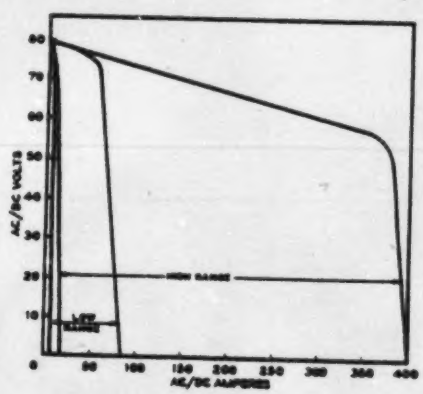
The duty cycle of a welding power source is the percentage of a ten minute period that a welding power source can safely be operated at a given output. This welding power source is rated at 60 percent duty cycle. This means that the welding power source can be safely operated at rated load for six minutes out of every ten. During the remaining four minutes, the unit should idle to permit proper cooling. If the welding amperes are decreased, the duty cycle will increase. Figure 4-3 enables the operator to determine the safe output of the welding power source at various duty cycles.

IMPORTANT

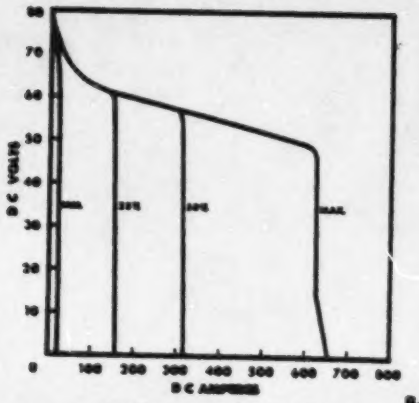
Exceeding the indicated duty cycle will cause the welding power source to overheat thereby causing damage to the welding power source.

A.13 VOLT-AMPERE CURVES (Figure A-4)

The volt-ampere curves show the output voltage available at any given output current within the limits of the minimum and maximum CURRENT CONTROL settings. Load voltage is predetermined to a large degree by arc characteristics. With the use of the volt-ampere curves, it is possible to determine the amperage possible for a specific load voltage. With reference to the volt-ampere curves, the curves show the maximum and minimum settings of the CURRENT CONTROL only. Curves of other settings will fall between the maximum and minimum curves shown.



300 Ampere Models



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500 Ampere Models

Figure A-4. Volt-Ampere Curves

A.14 METERS (If Applicable) (Figure A-1)

The meters can be mounted on the front panel of the welding power source and are for monitoring the welding operation and serve as an indication of the welding process. The meters are not intended for exact current or voltage measurements. These meters are internally connected to the welding power source output terminals. The voltmeter will indicate the dc voltage at the secondary terminals, but will not necessarily indicate the actual voltage at the welding arc. The ammeter will indicate the current output of the welding power source.

A.15 PULSER SWITCH (Optional Pulser Model Only) (Figure A-1)

The PULSER switch governs the operation of the pulse unit within the welding power source. By placing the PULSER switch in the ON position, the welding power source output current will pulse between the background current level and the peak current level. By placing the PULSER switch in the OFF position, the welding power source output will not pulse, but rather remain at the peak current level.

The PULSER switch may be placed in either the ON or OFF position prior to or during welding operations. If the PULSER switch is placed in the ON position prior to welding operations, the output current may be at either the peak or background current level. If the PULSER switch is placed in the ON position during weld operations, the pulsing begins with the output current remaining at the peak current level; then upsloping or downsloping to the background current level.

There is no interaction between the BACKGROUND CURRENT control, PULSES PER SECOND control, % ON TIME control, or the PULSER switch and any of the other welding power source controls, including the start current controls. If the CRATER FILL switch is in the IN position, both the peak and background output currents decrease by the same proportion.

Pulsing operations may be performed when the AC/DC switch is in either the AC or DC position.

When remote control of the output current is employed, only the peak current level is remotely controlled; the background current level is still established by the position of the BACKGROUND CURRENT control.

% ON TIME CONTROL (Optional Pulser Model Only)

The % ON TIME control provides pulse width selection of the welding power source output current. The % ON TIME control is operational only when the PULSER switch is in the ON position.

Rotating the % ON TIME control in a clockwise direction increases the peak current "on-time" relative to the entire pulse time; the balance of the time is background current. Hence, this control establishes the peak current pulse width relative to the entire pulse width, and is adjustable from 5% peak ON TIME to 95% peak ON TIME.

The scale surrounding the % ON TIME control is calibrated in percentage and should not be misconstrued as a time indication.

NOTE

The contacts of the % ON TIME control are of the continuous type, thereby making it possible to adjust this control while welding.

A.17 PULSES PER SECOND CONTROL (Optional Pulser Model Only) (Figure A-1)

The PULSES PER SECOND control provides pulse frequency selection of the welding power source output current. The PULSES PER SECOND control is operational only when the PULSER switch is in the ON position.

Rotating the PULSES PER SECOND control in a clockwise direction increases the pulse frequency, and is adjustable from 0.5 PPS to 10 PPS.

The scale surrounding the PULSES PER SECOND control is calibrated in pulses per second to aid in the selection of a pulse frequency suitable for the application.

NOTE

The contacts of the PULSES PER SECOND control are of the continuous type, thereby making it possible to adjust this control while welding.

A.18 BACKGROUND CURRENT CONTROL (Optional Pulser Model Only) (Figure A-1)

The BACKGROUND CURRENT and CURRENT CONTROL provide current selection within the welding power source output current range being used. The setting of the BACKGROUND CURRENT control establishes the output current background level from which the output current travels to the output current pulse level established by the setting of the CURRENT CONTROL. If the CURRENT CONTROL is adjusted to a setting below the BACKGROUND CURRENT control, there will be negative pulse peaking from the background reference level. Similarly, if the CURRENT CONTROL is adjusted to a setting above the BACKGROUND CURRENT control, there will be positive pulse peaking from the background reference level. Rotating the CURRENT CONTROL and BACKGROUND CURRENT control in a clockwise direction increases the output current.

The scale surrounding the BACKGROUND CURRENT control is calibrated in percentage and should not be misconstrued as an amperage or voltage reading. It is recommended that meters be read whenever it is necessary to know the amperage and voltage output.

NOTE

The contacts of the CURRENT CONTROL and BACKGROUND CURRENT control are of the continuous type, thereby making it possible to adjust these controls while welding.

A.19 COOLANT-GAS PRE-FLOW CONTROL & SWITCH (Optional) (Figure A-1)

An adjustable 0 to 15 second coolant-gas PRE-FLOW TIME control can be provided for controlling the period of time shielding gas and coolant flows before the arc is initiated. The PRE-FLOW TIME control governs the operation of a pre-flow timer within the welding power source.

Rotating the control in a clockwise direction increases the pre-flow time. The scale surrounding the PRE-FLOW TIME control is calibrated in seconds to aid in the selection of a pre-flow time period suited to the individual welding operation.

As soon as the remote contactor control switch has been closed, the pre-flow timer begins to time out the selected period of pre-flow time. Once the timer has timed out, the gas and coolant valves remain open and the contactor closes

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providing weld power. The timer then automatically resets and is ready for another weld cycle.

When coolant-gas pre-flow is desired, the PRE-FLOW TIME switch must be placed in the ON position. Conversely, by placing the PRE-FLOW TIME switch in the OFF position, coolant-gas pre-flow is not available, despite the position of the PRE-FLOW TIME control.

CAUTION

Prior to welding, it is imperative that proper protective clothing (welding coat and gloves) and eye protection (glasses and/or welding helmet) be put on. Failure to comply may result in serious and even permanent bodily damage.

14. Commence welding.

A.20 GAS TUNGSTEN-ARC WELDING (GTAW)

1. Make all necessary connections as instructed in Section 3.
2. Place the CONTACTOR switch in the REMOTE position.
3. If a remote current control is not to be used, place the CURRENT switch in the PANEL position. If a remote current control is to be used, place the CURRENT switch in the REMOTE position.
4. Place the HIGH-FREQUENCY switch in the desired position and rotate the HIGH-FREQUENCY INTENSITY control to the desired position.
5. Place the CRATER FILL switch in the desired position. If the CRATER FILL switch is placed in the IN position, the CURRENT switch should be placed in the PANEL position and the CONTACTOR switch should be placed in the REMOTE position.
6. Place the START CURRENT switch in the desired position. If this switch is placed in the ON position, rotate the START CURRENT control to the desired position.
7. Rotate the AC BALANCE control to the desired position:
   a. BALANCED for dc welding.
   b. Towards MAX. PENETRATION for less cleaning action and more penetration, or towards MAX. CLEANING for more cleaning action and less penetration when ac welding.
8. Rotate the POST-FLOW TIME control to the desired coolant-gas post-flow time. If the welding power source is equipped with a PRE-FLOW TIME control (optional) set the PRE-FLOW TIME controls as instructed in Section 4-19. If coolant-gas pre-flow is not desired, place the PRE-FLOW TIME switch in the OFF position.
9. Place the AC/DC switch in the desired position.
10. If the AC/DC switch has been placed in the DC position, place the POLARITY switch in the desired position. (The POLARITY switch is disabled when the AC/DC switch is placed in the AC position.)
11. Place the RANGE switch in the desired position if applicable.
12. Rotate the CURRENT CONTROL or remote current control, if used, to the desired position.
13. If the welding power source is a PULSER equipped model, and the arc pulsing function is desired, set the PULSER controls as instructed in Section 5-3. If arc pulsing is not desired, place the PULSER switch in the OFF position.
14. If the welding power source is equipped with a SPOT TIME function (optional) and spot welding capability is not desired, place the SPOT TIME switch in the OFF position. If spot welding capability is desired, make necessary adjustments as instructed in Section 4-20 and Section 5-4.
15. Place the POWER switch in the ON position.

CAUTION

Prior to welding, it is imperative that proper protective clothing (welding coat and gloves) and eye protection (glasses and/or welding helmet) be put on. Failure to comply may result in serious and even permanent bodily damage.

16. Commence welding.

A.21 PULSER OPERATION (Optional Pulser Models Only)

1. Make all necessary connections as instructed in Section 3.
2. Place the CONTACTOR switch in the desired position.
3. If a remote current control is not to be used, place the CURRENT switch in the PANEL position. If a remote current control is to be used, place the CURRENT switch in the REMOTE position. During pulsing operation, the panel CURRENT CONTROL becomes the "peak" current control. If a remote current control is used, it becomes a vernier percent peak current setting of the panel CURRENT CONTROL.
4. Place the HIGH-FREQUENCY switch in the desired position and rotate the HIGH-FREQUENCY INTENSITY control to the desired position.
5. Place the CRATER FILL switch in the desired position. If the CRATER FILL switch is placed in the IN position, the CURRENT switch should be placed in the PANEL position and the CONTACTOR switch should be placed in the REMOTE position.
6. Place the START CURRENT switch in the desired position. If this switch is placed in the ON position, rotate the START CURRENT control to the desired position.
7. Rotate the AC BALANCE control to the desired position:
   a. BALANCED for dc welding.
   b. Towards MAX. PENETRATION for less cleaning action and more penetration, or towards MAX. CLEANING for more cleaning action and less penetration when ac welding.
8. Rotate the POST-FLOW TIME (and the PRE-FLOW TIME, if the unit is so equipped) controls to the desired coolant-gas flow time.
9. Place the AC/DC switch in the desired position.

10. If the AC/DC switch has been placed in the DC position, place the POLARITY switch in the desired position. (The POLARITY switch is disabled when the AC/DC switch is placed in the AC position.)

11. Place the RANGE switch in the desired position if applicable.

12. Rotate the panel CURRENT CONTROL to the peak current desired.

13. If the welding power source is equipped with a SPOT TIME function (optional), place the SPOT TIME switch in the OFF position.

14. Rotate the BACKGROUND CURRENT control to the desired position. (The 0-100 graduations represent minimum to maximum of the range in use, and are approximately linear.)

15. Rotate the PULSES PER SECOND control to the desired number of pulses per second.

16. Rotate the % ON TIME control to the desired ratio of peak current time to background current time.

17. Place the PULSER switch in the ON position. Place the POWER switch in the ON position.

18. If the machine is equipped with meters and it is desired to observe the pulsing action, background current set point, etc.:

    a. Set the PULSES PER SECOND control to .5 pulse per second.

    b. Short the electrode to the work.

    c. Set the % ON TIME control to 95%.

    d. Energize the contactor and observe the peak current.

    e. Rotate the % ON TIME control to 5%, and observe the background current level; adjust to desired position.

    f. Remove short circuit, return the PULSES PER SECOND and % ON TIME controls to their respective proper set points.

NOTE

All pulser controls may be adjusted while welding.

APPENDIX B. WELDING CAREER STATISTICS

APPENDIX B. WELDING CAREER STATISTICS

The following statistics are reprinted from Welding Design And Fabrication, November, 1973.

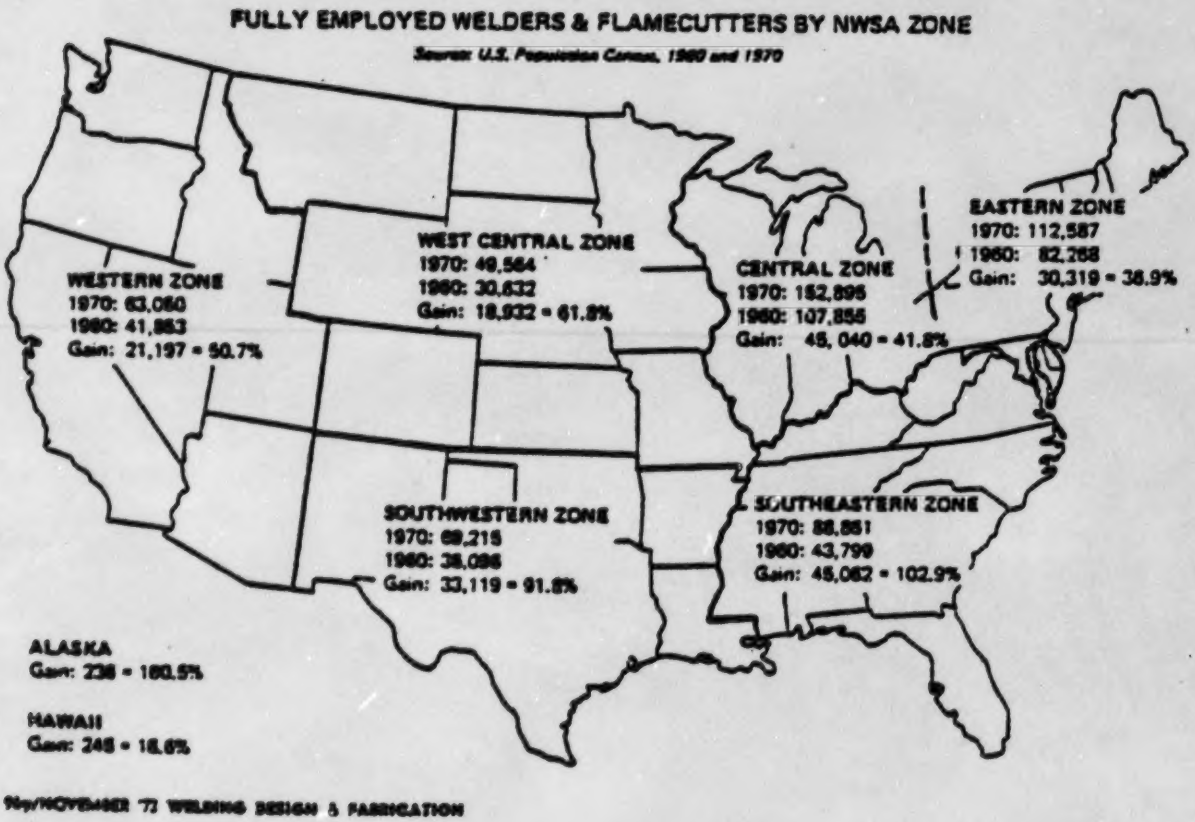

TABLE B-1.

FULLY EMPLOYED WELDERS & FLAMECUTTERS — U. S. CENSUS OF POPULATION

	ITEM	1970			1960			CHANGE, 1960-1970	
		Number	% of Total	Rank	Number	% of Total	Rank	Number	% Increase
	U. S. TOTAL	538,199	100	....	344,385	100	....	193,814	56.2
	TOP 10 States in 1970								
	Pennsylvania	43,895	8.156	1	32,527	9.445	1	11,368	34.9
	Ohio	41,812	7.768	2	27,924	8.108	4	13,888	49.7
	California	41,231	7.661	3	29,337	8.519	2	11,894	40.5
	Texas	38,715	7.193	4	20,657	5.998	6	18,058	87.4
	Michigan	37,303	6.931	5	28,192	8.186	3	9,111	32.4
	Illinois	34,651	6.438	6	24,206	7.029	5	10,445	43.2
	New York	25,723	4.779	7	19,446	5.647	7	6,277	32.2
	Indiana	22,176	4.120	8	13,765	3.997	9	8,411	61.1
	Wisconsin	16,953	3.150	9	13,768	3.998	8	3,185	23.2
	Louisiana	14,627	2.718	10	6,871	1.995	12	7,756	113.0
	TOP 10 SMSA's in 1970								
	Detroit	18,267	3.394	1	14,588	4.236	1	3,679	25.2
	Chicago	17,922	3.330	2	13,462	3.909	3	4,460	33.2
	Los Angeles,-Long Beach	16,717	3.106	3	14,467	4.201	2	2,250	15.6
	Philadelphia	12,673	2.355	4	11,621	3.374	4	1,052	9.0
	Houston	10,220	1.899	5	4,432	1.287	11	5,788	130.0
	New York	9,541	1.773	6	8,645	2.510	5	896	10.4
	Pittsburgh	9,251	1.719	7	7,127	2.069	6	2,124	29.8
	St. Louis	7,396	1.374	8	4,972	1.444	9	2,424	48.8
	Cleveland	7,059	1.313	9	4,876	1.416	10	2,193	45.0
	Milwaukee	6,730	1.250	10	6,149	1.785	7	1,685	27.4
	TOP 10 Employing Industries in 1970 *For additional information, see pages 96kk and 96ll*								
SIC	*Industry*								
37	Transportation Equipment	97,053	18.1	1	72,425	21.0	1	24,628	34.0
34	Fabricated Metal Industries	79,826	14.9	2	51,593	15.0	3	28,233	54.7
35	Machinery Except Electrical	77,804	14.5	3	51,713	15.0	2	26,091	50.5
15, 16, 17	Construction	60,135	11.2	4	29,497	8.6	4	30,638	104.0
33	Primary Metal Industries	36,121	6.7	5	26,437	7.7	6	9,684	36.6
75, 76	Repair Services	35,322	6.6	6	28,016	8.1	5	7,306	26.1
36	Electrical Machinery	30,415	5.7	7	15,134	4.4	7	15,281	101.0
50	Wholesale Trade	14,437	2.7	8	6,387	1.9	12	8,050	126.0
10-14	Mining	11,807	2.2	9	6,962	2.0	10	4,845	69.6
24, 25	Lumber, Wood Prod. Furniture & Fixtures	9,737	1.8	10	6,328	1.8	13	3,409	53.9

TABLE B-2.

EMPLOYMENT OF WELDERS & FLAMECUTTERS BY INDUSTRY

SIC		Industry	1970			1960			Increase - 1960 to 1970	
Div.	Major Group		Number	% of Total	Rank	Number	% of Total	Rank	Number	% Inc.
A	01-09	Agriculture, Forestry & Fisheries	2,216	0.41	22	509	0.15	24	1,707	335.4
B	10-14	Mining, Quarrying & Petroleum Extraction	11,807	2.19	9	6,962	2.08	10	4,845	69.6
C	15-17	Construction	60,135	11.17	4	29,497	8.82	4	30,638	103.9
D	20-39	Manufacturing	*372,344*	*69.18*	—	*242,371*	*72.44*	—	129,973	53.6
	20	Food & Kindred Products	3,799	0.71	19	2,111	0.63	18	1,688	80.0
	21, 29, 31	Other Nondurable Goods	6,236	1.16	16	(a)	—	—	—	—
	22	Textile Mill Products	1,182	0.22	29	1,045	0.31	22	137	13.1
	23	Apparel & Other Fabricated Textile Products	334	0.06	34	171	0.05	28	163	95.3
	24, 25	Lumber, Wood Products, Furniture & Fixtures	9,737	1.81	10	6,328	1.90	13	3,409	53.9
	26	Paper & Allied Products	3,158	0.59	20	(a)	—	—	—	—
	27	Printing, Publishing & Allied Industries	1,165	0.22	31	104	0.03	29	1,061	1020.2
	28	Chemicals & Allied Products	6,932	1.29	15	5,567	1.66	14	1,365	24.5
	30	Rubber & Misc. Plastic Products	1,903	0.35	23	1,203	0.36	21	700	58.2
	32	Stone Clay & Glass Products	7,340	1.36	14	(a)	—	—	—	—
	33	Primary Metal Industries	36,121	6.71	5	26,437	7.90	6	9,684	36.6
		331 Primary Ferrous	*30,358*	*5.64*	—	*22,989*	*6.90*	—	7,369	32.1
		333 Primary NonFerrous	*5,763*	*1.07*	—	*3,448*	*1.03*	—	2,315	67.1
	34	Fabricated Metal Industries	79,826	14.83	2	51,593	15.42	3	28,233	54.7
		34 — All Fab. Metal Ind. Except Ordnance	*76,588*	*14.23*	—	—	—	—	—	—
		348 Ordnance	*3,238*	*0.60*	—	—	—	—	—	—
	35	Machinery, Except Electrical	77,804	14.46	3	51,713	15.46	2	26,091	50.5
	36	Electrical Machinery	30,415	5.65	7	15,134	4.52	7	15,281	101.0
	37	Transportation Equipment	97,053	18.03	1	72,425	21.65	1	24,628	34.0
		371 Motor Vehicles & Equipment	*49,274*	*9.16*	—	*37,972*	*11.35*	—	11,302	29.8
		372 Aircraft & Parts	*9,056*	*1.68*	—	*7,630*	*2.28*	—	1,426	18.7
		37—All Other (Ships, Railroad Equip. Etc.)	*38,723*	*7.20*	—	*26,823*	*8.02*	—	11,900	44.4

TABLE B-3.

INDUSTRIES RANKED BY EMPLOYMENT OF WELDERS & FLAMECUTTERS – 1970

(For comparison with 1960 Census, see pages 96kk and 96ll, Nov. 1973)

Rank	SIC	Industry	Number	% of Total
1	37	Transportation Equipment	97,053	18.03
		371 Motor Vehicles & Equipment 49,274		
		372 Aircraft & Parts 9,056		
		37 All other: Ships, Railroad Equipment, Etc. 38,723		
2	34	Fabricated Metal Industries	79,826	14.83
		34 All Fab. Metal Ind. Except Ordnance 76,588		
		348 Ordnance 3,238		
3	35	Machinery, Except Electrical	77,804	14.46
4	15-17	Construction	60,135	11.17
5	33	Primary Metal Industries	36,121	6.71
		331 Primary Ferrous Industries 30,358		
		333 Primary Nonferrous Industries 5,763		
6	75, 76	Repair Services	35,322	6.56
7	36	Electrical Machinery	30,415	5.65
8	50, 51	Wholesale Trade	14,437	2.68
9	10-14	Mining, Quarrying, Petroleum Extraction	11,807	2.19
10	24-25	Lumber, Wood Products, Furniture & Fixtures	9,737	1.81
11	49	Utilities & Sanitary Services	9,598	1.78
12	40	Railroads & Railway Express Service	9,569	1.80
13	38, 39	Other Durable Goods	9,339	1.74
14	32	Stone, Clay & Glass Products	7,340	1.36
15	28	Chemicals & Allied Products	6,932	1.29
16	21, 29, 31	Other Nondurable Goods	6,236	1.16
17	91-97	Public Administration	5,824	1.08
18	52-54, 56-59	Retail Trade, Except Automotive Dealers & Gasoline Stations	4,265	0.79
19	20	Food & Kindred Products	3,799	0.71
20	26	Paper & Allied Products	3,158	0.59
21	41, 43-47	Transportation Services Other Than Railroads & Trucking	2,609	0.48
22	01-09	Agriculture, Forestry & Fisheries	2,216	0.41
23	30	Rubber & Miscellaneous Plastic Products	1,903	0.35
24	42	Trucking Service & Warehousing	1,684	0.31
25	73	Business Services	1,582	0.29
26	82	Educational Services	1,571	0.29
27	72, 78, 81, 83, 84, 86, 88	Services, Other Than Those Listed Separately	1,461	0.27
28	89	Other Professional & Related Services (Engineering, Etc.)	1,262	0.23
29	22	Textile Mill Products	1,182	0.22
30	55	Automotive Dealers & Gasoline Stations	1,173	0.22
31	27	Printing, Publishing & Allied Industries	1,165	0.22
32	60-67	Finance, Insurance & Real Estate	440	0.08
33	80	Health Services	409	0.08
34	23	Apparel & Other Fabricated Textile Products	334	0.06
35	79	Entertainment & Recreation Services	283	0.05
36	48	Communication	163	0.03
37	70	Hotel & Lodging Establishments	45	0.01
		TOTAL	538,199	100.0

APPENDIX C. WOMEN IN WELDING

SECTION C-1. A CAREER WITHOUT SEX BIAS

The vocational educator plays an important role in offering training in non-traditional areas by developing their programs to help break down the barriers to sex stereotyping.

Future growth in gas tungsten arc welding (more growth than the total welding market) will create an increasing demand for trained welders. Women have worked for many years as welders in the aircraft industries where the gas tungsten arc process is widely used. With the introduction of the manual pulsed-TIG process new opportunities are available to women because of the relative ease that an acceptable X-ray quality weld can be made by the "stiching method of overlapping spot welds".

Today, many years after the heyday of "Rosie the Riveter", when millions of women went to work in war-time-production plants, women are still pursuing careers as professional welders. These well-paying craft jobs provide opportunities for advancement and job satisfaction and are growing in popularity among women.

United States Labor Depatment manpower projections for the 70's into the 80's point to skilled trades and apprentice

type jobs as an area of rapid employment increase. Women have both the necessary aptitudes and the potential skills to perform well in these trades.

In 1960 there were 277,140 women employed as craft workers. By 1973 there were over 561,000 women in crafts jobs, a total of 4% of the work force. Today women account for 6% of the total work force in skilled trades.

A general survey has shown that the number of women employed as welders increased by 50% between 1970 and 1978. Their average hourly rate was $7.50. Many women have advanced into management, sales, and scientific occupations (metallurgy) with national companies. The American Welding Society today lists many women among its membership.

SECTION C-2. WOMEN ADVANCE IN SKILLED TRADES

The following article is reprinted with the permission of the American Welding Society.

WOMEN ADVANCE IN SKILLED TRADES/WELDER JUANITA CHAPMAN

Fred Kirby, American Welding Society

Well-paying craft jobs which provide opportunities for advancement and job satisfaction are growing in popularity among women.

U.S. Labor Dept. manpower projections for the 70's point to skilled trades and apprentice type jobs as an area of rapid employment increase.

In 1960, 277,140 women were employed as craft workers. In 1970, there were 494,871 women so employed. By 1973, 561,000 worked in the crafts representing 4% of the total workforce. Today, women account for 5% of the total workforce.

Women have the necessary aptitudes and potential skills to perform well in the skilled trades. In fact, in a research laboratory study of 22 inherent aptitudes and knowledge areas needed for jobs in the U.S., it was found there is no sex difference in 14 aptitudes. Women excel in six and men excel in two.

Juanita Chapman, 40, is a production welder at a huge A.O. Smith Corporation plant in Granite City, Illinois.

"If a woman does work, she wants to make enough in order to live comfortably," Juanita says. She points out that welding is a craft that not only pays quite well but offers considerable job satisfaction.

Women are choosing careers in the trades for reasons of simple economics. A good welder will make substantially more than a secretary, for example. Women have the same economic needs as men. Labor Dept. statistics show that experienced welders, plumbers and electricians earn an average of over $16,000 annually.

Before becoming a welder, Juanita was a housewife and part-time cleaner at a St. Louis broadcasting station making $2.55 an hour.

One day a girl friend said, "Let's sign up for welding school." Together they visited the Urban Technical Centers in downtown St. Louis and took the welding aptitude test. Shortly after, Juanita started welding training at Urban Tech on the U.S. Government sponsored WIN (Work Incentive) Program. The intensive five-hours daily training program was 14 weeks long including classroom and "hands-on" training using actual equipment. On completing the program, Juanita was skilled in arc welding, stick welding, MIG (metal inert gas) welding and well-grounded in welding theory.

Juanita's welding skills were very much in demand as is the case in the St. Louis area as well as nationwide where many opportunities exist for skilled welders. Like many technical schools that teach welding, Urban Tech considers job placement a most important part of the overall training scheme.

On a Friday, she completed training and started to work the following Monday at A.O. Smith after completing their welding aptitude test. That was December, 1976. Her starting wage was $5.57 hourly.

Today, she seam welds auto frames on the 3-11 p.m. shift and earns $7.75 an hour.

What about the reaction of co-workers in the traditionally male setting where of total plant employment of 2015, there are 52 females and eight female welders?

Juanita did not expect it to be easy and anticipated comments like "you make as much money as I make." Though somewhat lonely at first, she is now accepted as "one of the guys" and trades humor with the best of them.

Only three years ago, there were few opportunities for women in welding. This situation has changed completely. "Today, 90% of our women welding graduates available for work get jobs", according to an Urban Technical Institute representative.

Juanita adds, "I think the future for women in welding is excellent."

The American Welding Society offers a brochure on Welding CAREERS with information on welding job opportunities now available throughout industry and the skills and aptitudes necessary for a welder.

Address American Welding Society, 2501 N.W. 7th St., Miami, FL 33125, (305) 642-7090.